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AUTOMATIC ANTISUBMARINE TRACK RECONSTRUCTION

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AUTOMATIC ANTISUBMARINE TRACK RECONSTRUCTION

by

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ABSTRACT

The relative distance between various Antisubmarine Warfare vehicles is an important parameter for the evaluation of sensor equipment. This thesis presents a computer model, utilizing a time dependent error navigation system, Omega, for the determination of this relative distance parameter. A methodology for predetermining a relative distance error distribution for a specific area by simulating various Antisubmarine Warfare vehicle tracks from known navigational errors has been established. Attempts to smooth estimated tracks of Antisubmarine Warfare vehicles which receive the same time dependent navigational information simultaneously was found not to be advisable as this disturbs the correlation of navigation error between the vehicles.

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Section One

Introduction to the Problem

1-1 General Discussion of the ASW Exercise

The fleet's AntiSubmarine Exercises are an excellent example of the operational environment in which test and evaluation of weapon systems can be conducted. These exercises are necessary, for the sophistication and cost of the present state-of-the-art of military weapon systems requires that their capability be determined in this test and evaluation phase.

The ASW exercises not only provide the opportunity to observe the new system but also to train personnel and determine the effectiveness of the existing tactics and equipment. However, this method of evaluation is expensive which places additional emphasis on the essentiality of obtaining the best results which will in fact reflect the true capability of the weapon system.

1-2 Problem

One of the primary purposes of an ASW exercise is to provide data to evaluate the potential of detecting devices of the ASW forces. The interplay of the different vehicles involved (i.e. aircraft, surface ships and submarines) in an ASW exercise create a unique problem in that not only are their exact positions never established but also confirmation of detection by actual sightings are not always possible. This situation breeds the continually arising question, "Were any two vehicles within detection range of the detecting sensors?"

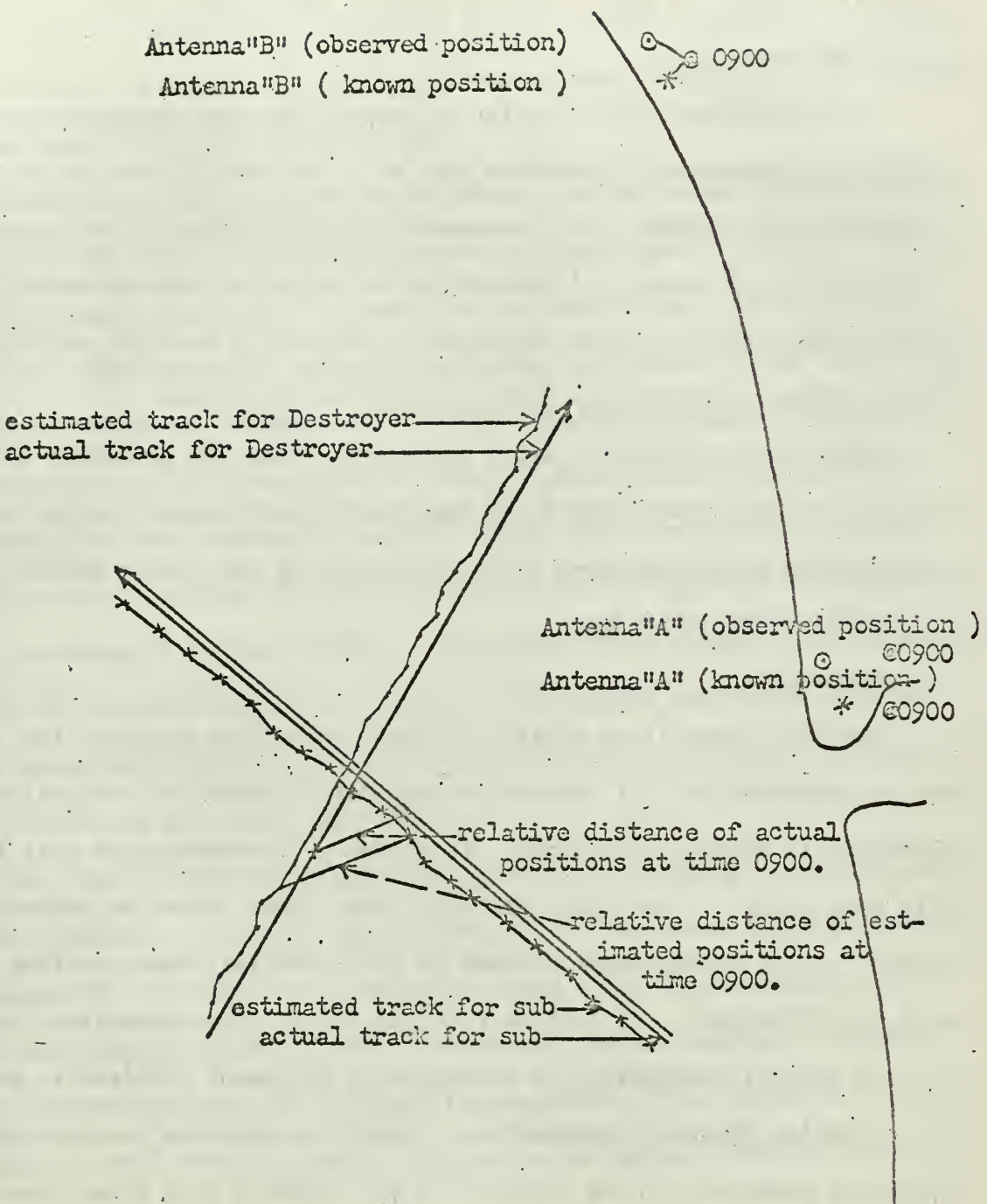
This question is hopefully resolved during the formal reconstruction of the ASW exercise which takes place after its termination. The personnel usually represented at these sessions are a mixture of those directly involved, along with the necessary analyst and administrative personnel.

One of their first tasks is to determine the tracks of the various vehicles by reconstructing them from the respective navigators' logs. The present reconstruction procedure is spelled out in great length which results in a process that is tedious and time consuming. [1] Unfortunately, even after these tracks have been reconstructed, serious doubt exist to their accuracy. The cause of this doubt does not arise from the reconstruction procedures but basically in its source of navigational information--the navigator's log.

The navigator's log is composed of information gathered from available navigational equipment on board the respective vehicles. The navigational errors present in the log are the result of an accumulation of navigational equipment and human errors. The relative distance between any two vehicles in question is of primary interest in this reconstruction session. The error in this relative distance between any two vehicles (i.e. see figure 1) results from a combination of their separate inherent navigational errors. Knowledge concerning this relative distance error is presently not well formulated. But this relative distance error is one of the parameters necessary in analyzing the effectiveness of the detection equipment.

1-3 Objective

General Electric TEMPO, Santa Barbara, California is presently under contract with the United States Navy to investigate the problems introduced by the relative distance errors and to propose means of alleviating or reducing them. Smoothing techniques are being considered which would attempt to reduce the existing relative errors by smoothing the estimated positions found from present navigation information. The employment of a new type of navigational aid called OMEGA, which is in the operational-



Relative Distance Error = Relative distance of actual positions - Relative distance of estimated positions.

Omega receiver error = Known positions of antenna's - Observed positions for antenna's.

Figure # 1

evaluation stage, is under consideration as the primary source of navigational information.

It is therefore our objective to investigate the aforementioned alternatives and recommend a procedure that will aid considerably in the track reconstruction problem. Our recommendations will focus on two specific aspects, first a faster and more effective method of reconstructing the various ASW vehicles tracks and second to provide a means by which one could conduct a statistical error analysis of the tracks.

Hopefully our solution would effectively free the personnel at the reconstruction session from doing the actual track reconstructing themselves, thus permitting them to devote more time and energy towards strictly analyzing the exercises.

1-4 Approach

The first step is to tackle the basic underlying problem, that of errors introduced by all the various methods in which the navigation information is presently obtained. It cannot be overemphasized that if errors must exist, it is highly desirable that these errors be dependent in respect to the navigational systems of both vehicles, when relative accuracy is of interest. It follows that one should then concentrate on finding the optimal combination of navigational equipment required to provide this relative distance information. Clearly the minimum navigational information necessary is the position of each vehicle at a given time. However, in order that analysis be conducted, a sequence of such points must exist so that a continual picuture of the interplay is displayed. The time interval between the sequence of points depends on the speed at which the vehicles are traveling. The time interval between aircraft may be one minute while for submarine and surface vessels every five minutes may

be sufficient depending on the detail desired of the reconstructed tracks. This sequence of points is then basically a "dead-reckoning" track between navigational fixes for each vehicle.

The present methods employed to obtain the DR tracks are to begin at a fix obtained from a navigation source and apply course and speed information as one's guide until another fix is established. This requires continuous monitoring of compasses and speed indicators if one expects to obtain the required accuracy desired for detection equipment evaluation. This process has not proven desirable even after highly sophisticated equipment has been employed to automatically plot the tracks. One may suggest that more fixes be obtained so that the DR time can be shortened thus resulting in better accuracy. At present this suggestion is sound in theory but is not practical. The reason being that short time intervals (e.g. less than fifteen minutes) between fixes for a majority of present Naval crafts is not easily obtained.

The idea of receiving continuous fixes is intriguing, so let us pursue it further. A position can be obtained in two ways, first by knowing the range and bearing from a reference point. The second method is to find two lines of positions which intersect. Since reference positions (i.e. land masses) are non-existant the majority of the time, the intersection of two lines of position appears to be the more desirable technique.

With this in mind, if one could monitor on board the ASW vehicles, some sort of navigational input signals that would establish their positions, then a continuous fix could be realized. This could be accomplished by putting on board the vehicles recorders which record these signals and the corresponding time. This procedure would also take the place of the

navigator's log - eliminating human errors.

Hopefully, if errors are introduced using this technique, they will be dependent to this technique and will not affect appreciably the relative accuracy between any two vehicles.

The optimal navigation system selected to be used in conjunction with this technique is one that is not only compatible to a continuous readout but also possessing errors which result from a source common to all vehicles in the immediate vicinity, e.g. variations in the velocity of wave propagation. We propose that the Omega navigation system now in the operational-evaluation stage, which possesses these desired characteristics, be selected. However, any navigational system with these characteristics may be used.

In fact, we now have a navigation system, consisting of Omega navigational information, which can be monitored continuously and simultaneously by all vehicles.

Section Two

Omega

2-1 Introduction

Omega is a Very Low Frequency (VLF) navigation system operating in the internationally allocated navigation band in the electromagnetic spectrum between 10 and 14 Kc/s. (See Table 1 for further system characteristics). [2] As in Loran each pair of stations provides the navigator with a family of hyperbolic lines-of-position. The 5000 to 6000 nautical mile baseline between stations gives a global coverage capability with a maximum of only eight stations.

2-2 Propagation Medium

Most modern radio navigation systems are designed to obtain optimum results from propagation medium involved. From this follows the fact that most navigation systems are propagation limited. Omega is no exception. Capabilities and operational procedures stem in large part from the properties of VLF propagation. It should be noted that the propagation properties to be considered are solely those at the Omega frequencies. Much data has been acquired at the basic 10.2 Kc/s frequency so definite conclusions can be made. Omega is a simple system with range and accuracy based on the features of VLF propagation, second order effects are well understood although large. Easy to use corrections are prepared for use with Omega.

The most apparent feature of an Omega VLF phase difference measurement as observed at some remote stationary point is a diurnal variation. While day-night transitions result in large changes in position, they are normally quite regular and predictable. If the diurnal variation can be predicted it need only be subtracted from observed data to yield a navigation

Receiver Specification (Ground Monitor)

Frequency: 10.2 KC fixed or continuously tunable from 8.2 to 15.2 KC.

Sensitivity: 0.75 db noise figure.

Differential Amplitude: 80 db.

Input Impedance: 50 ohms.

Detection: Synchronous.

Instrumental Accuracy: 0.2% phase-difference of two noise-free signals.

Tracking: Zero velocity error servos.

Signal Conditions: Track reliably in signal-to-noise ratio of 1/10.

Commutator Synchronization: Semi-automatic operation in signal-to-noise ratios to 1/3.

Reference Oscillator: Long-time stability 1 part in 10^8 per day, short time stability 5 parts in 10^9 per 30 minutes.

Size: Height 57 ½", Width 19 ½", Depth 17 ½".

Weight: 486 pounds.

Power: 115 volts, single phase, 60 cycles, 12 amperes.

Table 1

Omega Receiver Specifications

variate which, to a good approximation, varies quite regularly with position.

2-3 Accuracy

Factors effecting the accuracy (i.e. the magnitude of the navigational error) to be obtained from a practical navigation system include: repeatability of observations such as day-to-day variations at a particular site, accuracy with which observed readings may be associated with real terrain features, and degradation experienced in actual operations due to shipboard installation or procedures.

Although Omega is an absolute system, relative accuracy is important in many applications. Because the limitations on Omega accuracy is the phase stability of a transmission through long distances, phase perturbations of a signal from a remote transmitter at any two receiving sites in the same neighborhood will be much the same. Relative accuracy is therefore significantly better than absolute accuracy. It is also indicative of relative positioning capability with a task force. As separation distance between receivers decreases, the relative accuracy increases.

The additional difference between the experimental and operational systems must be taken into account. The experimental system used short-term synchronization, that is, propagational fluctuations on the path between two Omega transmitters which were fed into the phase radiated by one of the transmitters. In the operational system, the synchronization will be achieved through the use of very stable oscillators, using a time constant of one or more days. Thus the phase will be radiated at a constant value and corrected only slowly to keep it at the assigned value.

The effect of this procedure would reduce the operational error to 2/3 those of the experimental system. Thus we can predict that the

standard deviation of the operational line-of-position errors for daytime will be 0.32 miles and nighttime, 0.82 miles. [3]

In the case of the non-correlated lines of position, the root-mean-square fix error is usually taken as the square root of the sum of the squares of the two line-of-position errors divided by the sine of the crossing angle between the two lines of position. If the two position lines have the same accuracy we can compute a daytime rms fix error of 0.48 miles and a nighttime rms fix error of 1.22 miles. [3]

Section Three

Determination of Relative Distance Error Distribution

3-1 Omega Implementation

At the initial planning stages of an ASW exercise, recorders capable of recording Omega information from the receivers which in turn receive signals simultaneously from two different pairs of pre-selected Omega transmitters will be installed. The tapes of raw recorded Omega data for each individual vehicle will be transferred to a computer facility when convenient or at the termination of the ASW exercise. The tapes will then be processed in order that the navigation information is in proper form for reading into a computer program. A computer program, such as the one referenced in Appendix B, will reconstruct the vehicle tracks in such a manner as to provide the user with relative distance information of selected vehicles (i.e. permutations of aircraft and destroyers with submarines). With this relative distance information, an analysis regarding whether or not any two vehicles were within detection range for a particular sensor can be accomplished with the aid of a relative distance error distribution.

3-2 Preliminary Determination of a Relative Distance Error Distribution

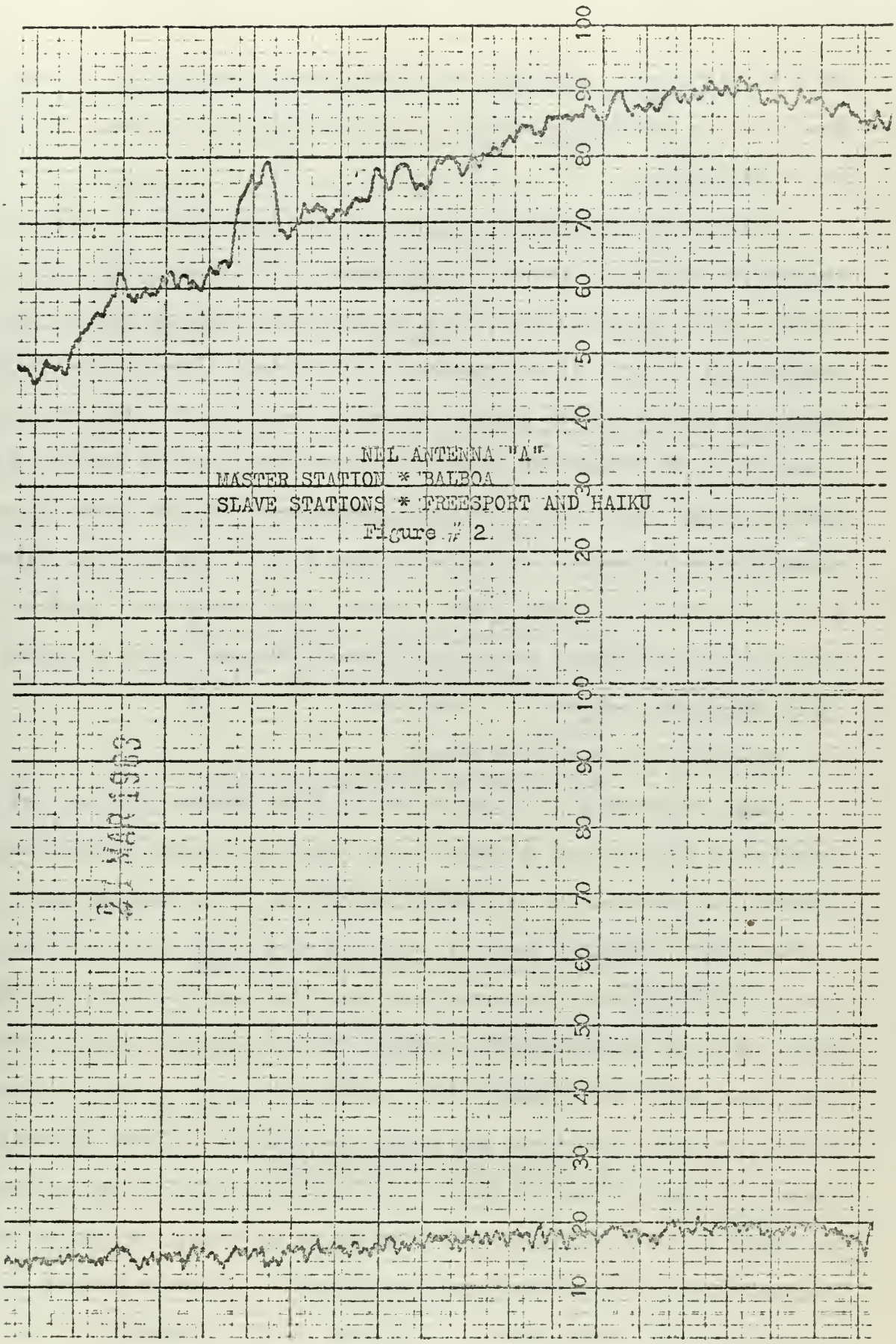
The actual tracks along with the estimated tracks of the vehicles must be available in order to determine the relative distance error distribution for an area. The actual track of a specific vehicle is defined as that track which is not in error. The estimated track is defined as that track which incorporates the error inherent to the Omega navigation system. With the above two tracks defined, the relative distance error at any given time is that value obtained by subtracting the distance between the actual positions of the two vehicles from the distance between

their estimated positions, as shown in figure 1.

It is immediately apparent that the actual tracks of the various vehicles are not obtainable because a navigator cannot be sure of his exact position. Our solution to this aforementioned problem has been to simulate hypothetical ASW tracks and refer to them as the actual tracks of the ASW vehicles. The estimated tracks, on the other hand, corresponding to these actual tracks can be determined by incorporating known errors from a pair of Omega receivers. These Omega receiver errors can be obtained by observing the difference between the known fixed position of the receiver's antenna and the position observed from the resulting navigational information being received at a given time, as depicted in figure 1. It follows that these actual tracks will be constructed in the general area, a reasonable distance from the antenna, and in a corresponding time frame with the antenna. At this point it is necessary for our determination of the relative distance error distribution to assume that the dominate error inherent to the Omega navigational system is in fact the variation in the velocity of the electromagnetic waves in the media and is not appreciably affected by the mode of travel of the receivers. This assumption is based on the fact that the Omega system operates on the phase difference concept which is not disturbed by the mode of travel, although the signal-to-noise ratio may be affected.

3-3 Simulation inputs

The simulated estimated tracks make use of Omega strip charts received from the Naval Electronics Laboratories, San Diego, during the period of 1-31 March 1963 (see figure 2). Strip charts were used from three different receiving antennas located in the San Diego area and two more receiving antennas located in the Pt. Mugu and Pt. Huenume areas. This


100
90
80
70
60
50
40
30
20
10
NEL ANTENNA "A"
MASTER STATION * BALBOA
SLAVE STATIONS * FREESPORT AND HAIKU
Figure # 2
100
90
80
70
60
50
40
30
20
10

gives a capability of getting simultaneous Omega navigational information from the five different sources to that simulations of various vehicles can be achieved.

To determine the Relative Distance Error Distribution, a computer program was written to gather this necessary information using as its primary inputs raw Omega data, time and Longitude-Latitude data of the hypothetical tracks. It was necessary to physically interpolate the raw Omega data from the strip charts. It may be pointed out here that this interpolation technique may introduce errors independent of the Omega navigation system error itself, but the maximum error was 100 yards in our interpolation procedure. It can be assumed that if our Relative Distance Errors are acceptable, when a more sophisticated technique is employed, better Relative Distance Errors should result because of the exclusion of these independent errors.

3-4 Determination of Antenna Errors

Omega strip chart information for two fixed antenna positions as a function of time is used as input to the computer program. The minimum interval of time used for the Omega readings was one minute because of the "seaman's eye" technique used for acquiring this information from the strip charts. Diurnal variation corrections were then applied to the raw Omega data. This was accomplished by reading into the program a matrix correction table which corresponded to the applicable period of time and location (i.e. month, day, hour, and longitude-latitude). Since this matrix varied not only in time but also in longitude-latitude, it was necessary to employ a linear interpolation technique to determine the appropriate correction for each input reading (see figure 3). As each reading was corrected it then went through a longitude-latitude conversion routine

SKYWAVE LINEAR INTERPOLATION CORRECTION ROUTINE

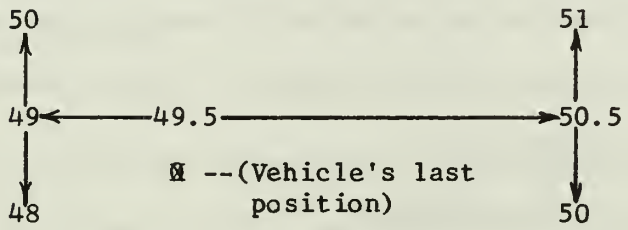
Selected Latitude-Longitude Outlay

50N-40W	50N-36W	50N-32W
	⊠--(Vehicle's last position)	
46N-40W	46N-36W	46N-32W
42N-40W	42N-36W	42N-32W

- -

Omega station pair correction values for Latitude-Longitude which enclose Vehicle's position for specified time

Time-0900



Linear interpolation between values

- -

Time Interpolation

Specified Latitude-Longitude value — Time 0900-48 / Time 1000-53

Time of position desired - 0930

Time(0900-0930)X(55-48)Value = 3.5

POSITION CORRECTION -- 49.5 + 3.5 = 53

Figure 3

Skywave Linear Interpolation Correction Routine

which is outlined in detail in Appendix C-III. Finally the vector error was found by comparing this converted reading which represents the estimated position of the antenna with the actual antenna position so that the inherent error associated for that particular antenna can be determined. This process was repeated for the entire input readings for both antennas.

At this point it is possible to determine the relative error necessary to determine the Relative Distance Error Distribution of the reconstructed tracks if one is completely convinced that maneuvering of the ASW vehicles have no effects on the relative error and if possible smoothing techniques were not to be investigated. This relative error can be simply found by algebraically subtracting the relative distance of the two actual positions of the antennas from the relative distance of their estimated positions at a given time (see figure 1).

3-5 Hypothetical Track Simulation

To add intuitive appeal to the problem, actual tracks simulating typical ASW tracks for aircraft, destroyers, or submarines were developed. This also allows the opportunity to investigate the effects of smoothing techniques on the overall relative distance error distribution. An auxiliary program (i.e. see Appendix A) was written to accept Longitude-Latitude information for constructing an "actual track". To these longitudes and latitudes at a given time were added the components of the vector error from one of the antenna's to obtain the estimated tracks (i.e. for example, antenna A's errors construct a submarine's estimated track and antenna B's errors construct a destroyer's estimated track as shown in figure 1.)

Smoothing techniques were then employed in an effort to smooth the derived estimated tracks. First by the use of the technique of fitting

the estimated track by the method of Least Squares Curve fitting with orthogonal polynomials (refer to Appendix C-II), and secondly by smoothing smaller segments of the estimated tracks known as the technique of Exponential smoothing (refer to Appendix C-I). A new relative Distance Error was determined by comparing this smoothed estimated track with the hypothetical track as a function of time.

The overall computer program not only has the capability of printing out all of the pertinent information such as the Relative Distance Errors, time, longitude and latitude as shown in Appendix A, but also prints a graphical representation of the actual, estimated and smoothed-estimated tracks as shown in Figure 4.

3-6 Results

Sample points used for determining the Relative Distance Error Distribution were generated from the raw Omega data. Partial sampling of the data was accomplished by using permutations of date and time intervals from the available data. As an example, a day's transition periods (i.e. sunrise and sunset) were included as well as continuous sections of day and nighttime readings. The antennas (i.e. those antennas located in San Diego, Pt. Mugu, Pt. Huenume area), which provided the raw Omega data, were located so that trials could be conducted on pairs of antennas which were not only in close proximity but also of considerable distance from one another (i.e. Pt. Huenume and San Diego).

A cumulative Distribution of the Relative Distance error (defined to be the probability that an observed value of the Relative Distance Error is less than or equal to some value) was found from using the data which included <u>all</u> the trials. The distribution is found to be Normal with a mean of -120 yards as shown in Figure 5. This mean implies that the

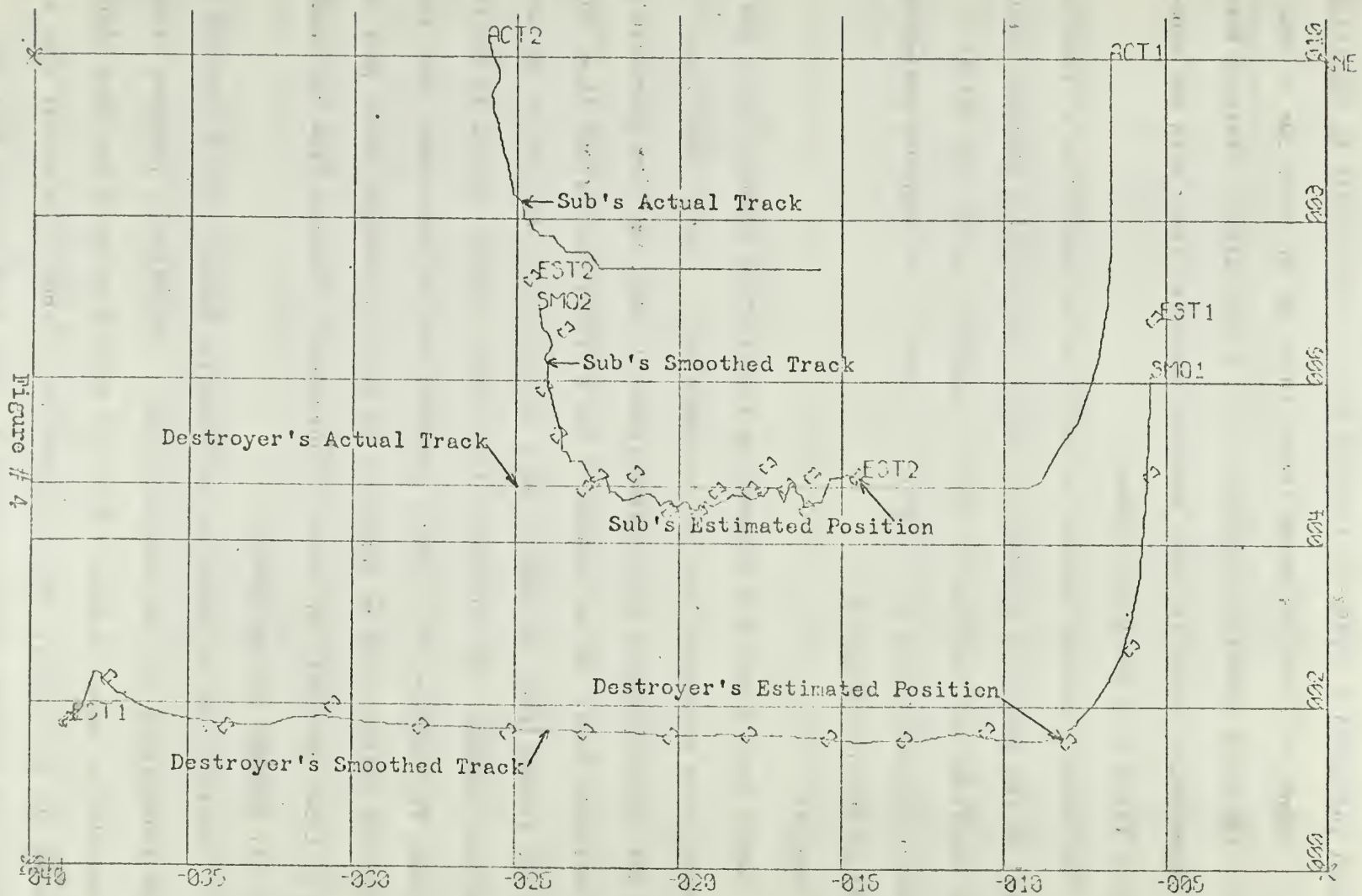
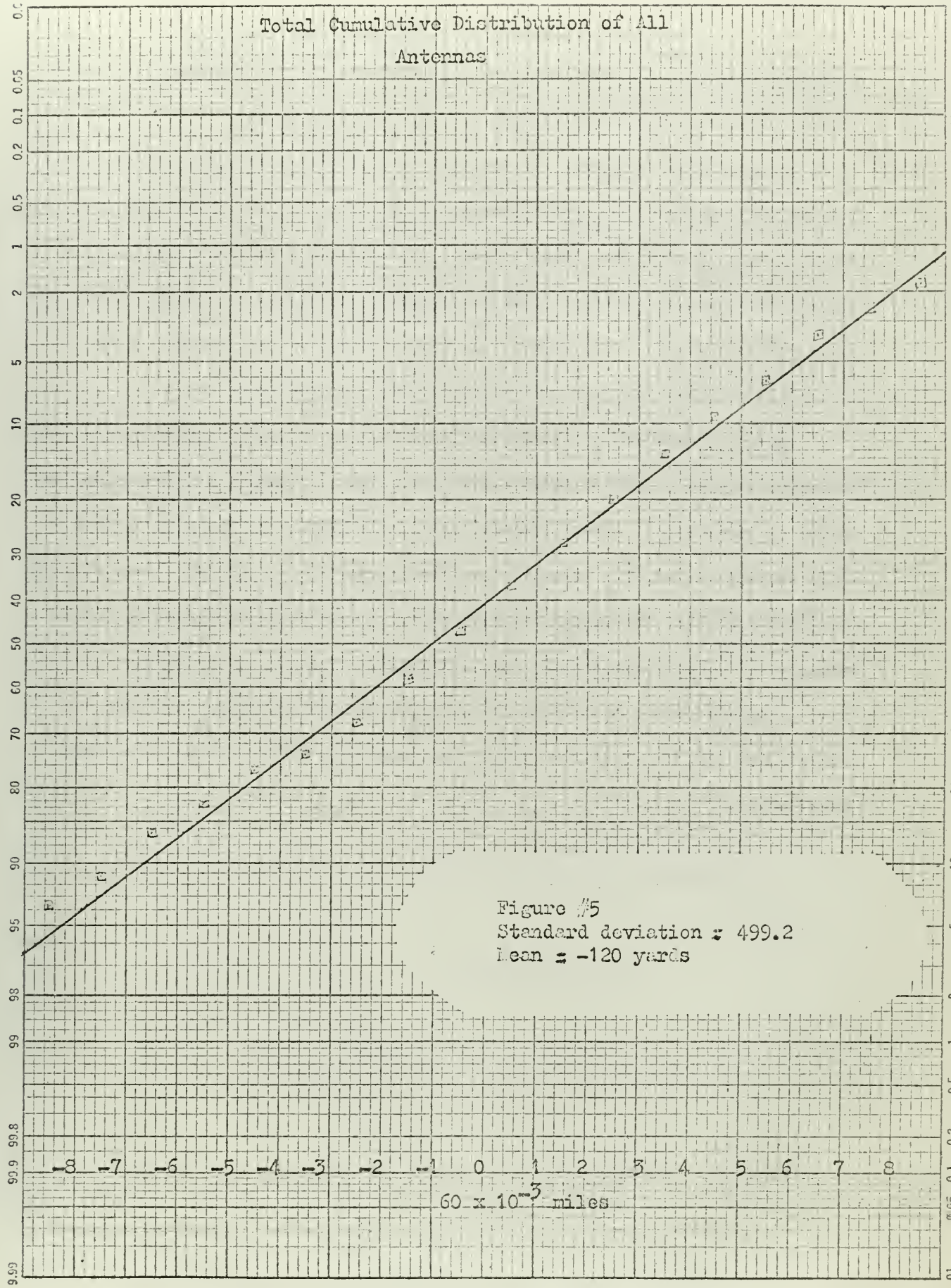


Figure # 4

X-SCALE = 5.00E-02 UNITS/INCH = 6000 yards

Y-SCALE = 2.00E-02 UNITS/INCH = 2400 yards

AUTOMATIC TRACK RECONSTRUCTION OF TWO ASW CRAFT


Total Cumulative Distribution of All Antennas
Figure #5
Standard deviation = 499.2
Mean = -120 yards
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8
60 x 10⁻³ miles

relative distance for the estimated tracks was on the average 120 yards longer than the relative distance of the actual tracks.

Investigated next was the cumulative Relative Distance Error Distribution for the relative error sample points associated with those antennas located only in the San Diego area. The analysis of this distribution showed that normality could not be assumed, as shown in Figure 6, and the mean was 3.2 yards. The above two distributions (i.e. Figures 5 and 6) cover the minimum and maximum distance for any two vehicles.

When the smoothing techniques were used on the estimated tracks, the Relative Distance Errors were about ten times as large as those found by using no smoothing. These results were attributed to the high degree of time dependency of the errors associated with the estimated track and the inability of the smoothing techniques to follow precisely the vehicle's maneuvers. The comparative results obtained are shown in Figure 7. It is recommended that no smoothing features be incorporated when two vehicles are obtaining simultaneous readings from their respective Omega receivers.

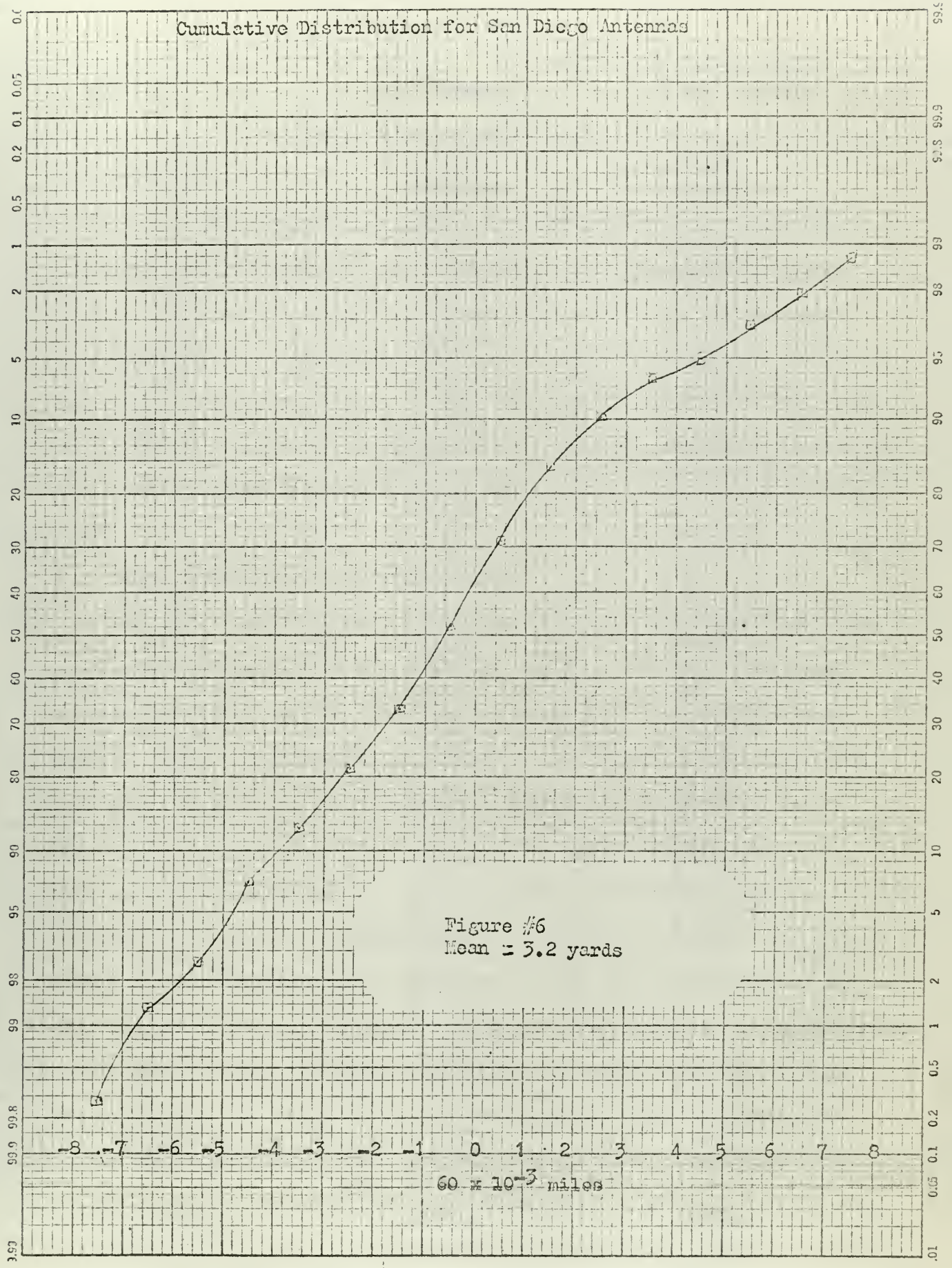


Figure #6
Mean = 3.2 yards

RELATIVE ERROR RELATIONSHIPS

Scale .001 = 120 yards

NON SMOOTHED	EXP SMOOTHED	LST SMOOTHED
.00013	.00013	.06116
.00064	-.03437	-.05186
-.00039	-.05581	-.07488
.00550	-.06338	-.06017
-.00088	-.05802	-.03834
.00211	-.00132	-.05308
.00184	.06297	-.07308
-.00098	.08056	-.05934
-.00030	.08104	-.03393
.00092	.06972	.00335
.00094	.04999	.03770
.00347	.02416	.06205
.00065	-.00201	.06606
.00453	-.01074	.08439
.00311	-.00052	.04427
-.00316	.01714	.01872
.00458	.03935	-.01111
.00301	.05518	-.02198
-.00035	.06737	.00960
-.00001	.12789	.11496
.00157	.10229	.16474
.00052	.02401	.08867
0	.01711	.12670
.00256	.00619	.10299
.00284	.00712	.05688
0	.01310	.12552
-.00029	.02266	.06102
.00198	.03477	.15927
.00173	.03961	.12613
.00196	.02802	.11921
-.00009	.00652	.07920
.00269	-.01872	.05783
.00088	-.04395	.04103
.00158	-.05701	-.00558
.00419	-.06138	.01193
.00024	-.06204	.01279
.00547	.01017	.13966
.00024	-.05360	.01041
.00052	-.00382	-.02811
.00007	.04052	-.01054
.00174	.06483	-.02365
-.00083	.07309	-.04730
-.00182	.07695	-.07489
-.00203	.08033	-.06956
-.00103	.08035	-.04083
-.00175	.07478	-.02961
-.00070	.06379	-.00233
.00084	.05022	.01569
.00046	.03889	.04124
-.00054	.00826	.04058
-.00063	-.01243	.06233
-.00096	-.03152	.07005
.00141	-.04543	.07621
.00439	-.04961	.10187
.00259	-.04870	.10908
.00213	-.03989	.14156
.00078	-.02740	.17135
.00110	-.00749	.15709
.00051	.01480	.16645
.00019	.03635	.13639
.00245	.05306	.08655

Time intervals one minute

Magnitude of Error

.00154 .04150 .06836

Figure #7

Section Four

Other Omega Applications

4-1 Introduction

If the Omega navigational system were employed as the primary data source for the reconstruction of ASW vehicles' tracks, one might expect instances in which continuous track information could not be obtained. This could be due to mechanical difficulties with the equipment, or, in the case of submarines engaged in evasive maneuvers, running at depths below the maximum depths for Omega reception. This requires investigation of techniques, applied to Omega data, to improve absolute navigational accuracies.

4-2 Omega-NonOmega Relative Error Accuracy

When only one of the two vehicles can receive Omega information continuously, the track of at least this one vehicle should be constructed, so that the tracks latitude and longitude are available for short increments of time. A representative sample of the absolute errors associated with these latitudes and longitudes are shown in Figure 8, under the column for non-weighted vehicles. It should be emphasized that these absolute errors were obtained from data collected in 1963 and present day refinements of Omega have predicted that standard deviations of the operational line-of-position errors during the daytime will be 0.32 miles and nighttime, 0.82 miles. [3] Trials simulating this situation were conducted using vector errors to determine the estimated track, which may be dependent with respect to other errors for that specific track, but independent of the errors associated with a second estimated track. One of the estimated tracks was assumed to be determined by the use of Omega and the other estimated track by some other navigational source such as satellite, celes-

Omega-NonOmega Weighing Technique

Scale .001 = 120 yards

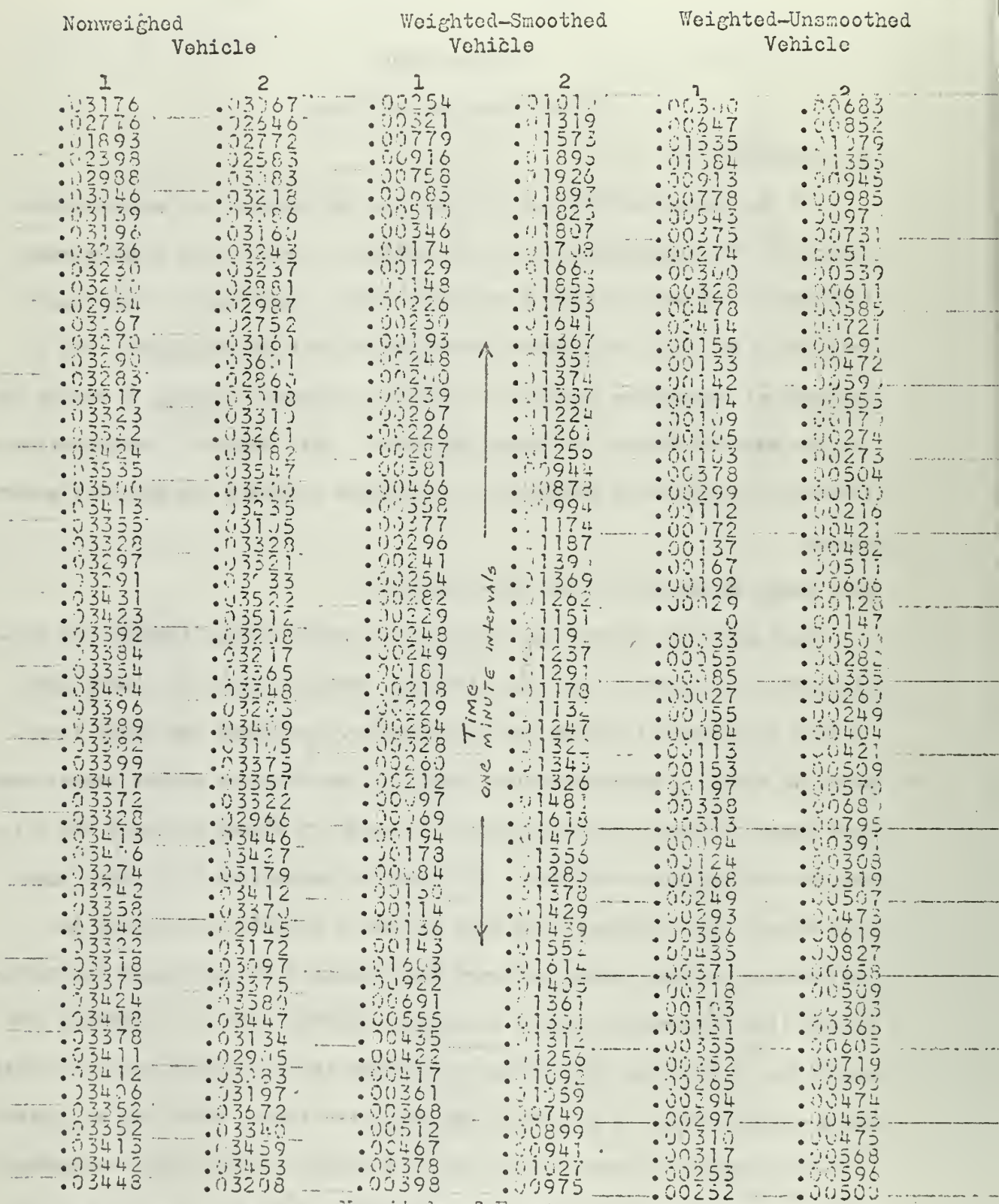


Figure #8

trial, loran or dead reckoning. Omega-NonOmega trials were used to determine if smoothing the Omega estimated track, can improve the relative distance errors. This would be expected if the errors in the estimated position for each vehicle are independent. Figure 9 shows the results from such trials and as expected it appeared that smoothing was in fact an improvement. It is suggested that the exponential smoothing method be used under Omega-NonOmega circumstances because of the fact that there are no navigational error correlations between the vehicles. Exponential smoothing was favored over least squares because of its ability to follow the vehicles maneuvers was more precise when a high smoothing constant, say $\alpha = .04$, was used. In actual practice the second track would be reconstructed in such a manner as to obtain the best absolute accuracy possible. This may be accomplished by various methods such as the procedures now being used in the formal reconstruction sessions or from recording continuous navigational information from a secondary source, e.g. ships inertial navigation system.

4-3 Improvement of Absolute Accuracies by Determining an Expected Estimated Position.

Improvement in the relative distance error can be realized under these Omega-NonOmega circumstances if one could reduce the absolute error of the Omega navigational system. Appropriate weighting of other navigational information is proposed. An expected estimated position is found by using other navigational information to a particular ship in conjunction with Omega. This may be accomplished by weighting the obtained latitudes and longitudes by some factor, say A_i, where i denotes a particular type of navigational system, and the sum of the A_i's must equal one. The value of A_i is obtained by a comparative judgement of the respective accuracies

OMEGA-NONOMEGA
RELATIVE DISTANCE ERROR RELATIONSHIP

Scale .001 = 120 yards

UNSMOOTHED	TIME	SMOOTHED
-.15818	9.00000	-.15818
-.15800	9.01000	-.19280
-.15598	9.02000	-.21319
-.15523	9.03000	-.22199
-.13984	9.04000	-.21270
-.08564	9.05000	-.15181
-.00224	9.06000	-.05617
.06662	9.07000	.04127
.11602	9.08000	.12463
.14201	9.09000	.17438
.14889	9.10000	.18653
.14676	9.11000	.17353
.11792	9.12000	.14529
.06049	9.13000	.10919
.00802	9.14000	.07043
-.03172	9.15000	.03909
-.06082	9.16000	.01617
-.07739	9.17000	.00188
-.08395	9.18000	-.00289
-.09620	9.19000	-.04181
-.08728	9.20000	.01449
-.04380	9.21000	-.04655
-.02436	9.22000	-.03583
-.00754	9.23000	-.03074
.01986	9.24000	-.00980
.04505	9.25000	.02057
.07301	9.26000	.05730
.09613	9.27000	.09514
.11758	9.28000	.12493
.13575	9.29000	.13547
.14282	9.30000	.12986
.14585	9.31000	.11329
.14673	9.32000	.09351
.13086	9.33000	.07815
.10557	9.34000	.06595
.05038	9.35000	.04815
.01973	9.36000	.03035
-.08292	9.37000	-.03679
-.11826	9.38000	-.05203
-.13408	9.39000	-.05868
-.13946	9.40000	-.06105
-.14484	9.41000	-.06404
-.14582	9.42000	-.06469
-.14551	9.43000	-.06261
-.14526	9.44000	-.06305
-.14274	9.45000	-.06749
-.13698	9.46000	-.07577
-.12898	9.47000	-.08569
-.12218	9.48000	-.09946
-.11790	9.49000	-.11585
-.11166	9.50000	-.13169
-.10474	9.51000	-.14537
-.09663	9.52000	-.15410
-.08998	9.53000	-.15414
-.07540	9.54000	-.14498
-.05336	9.55000	-.12370
-.02583	9.56000	-.09226
.00837	9.57000	-.04968
.05052	9.58000	.00449
.09101	9.59000	.06634
.11837	10.00000	.12363
.09660	Magnitude of Error	.09346

Figure #9

of the navigational sources (i.e. .3 (longitude / latitude) of Omega plus .7 (longitude / latitude) determined by loran / celestrial / satellite). From this expected estimated position and the estimated position found when using the Omega navigational system, a vector difference can be obtained. This vector difference is then applied to a number of past and future Omega positions. A sample of the results obtained when using this technique is displayed in Figure 8 with $\alpha = 0.4$. It may be desirable to incorporate a time factor, say B_i to the vector difference constant in order to take into account a decreasing effect on the vector error. It is recommended that this weighting technique be considered when Omega-NonOmega situations arise.

Section Five

Operational Program

The knowledge gained from Sections Three and Four was incorporated into the operational program (i.e. the program used at the reconstruction sessions) as shown in Appendix B. In Figure 10 a flow diagram is referenced which displays the basic features and the structure of the operational program.

The implementation of this operational program during the formal reconstruction of ASW exercises would provide relative distance information when Omega is recorded continuously by both vehicles. In conjunction with this relative distance information, employment of a previously determined Relative Distance Error Distribution (i.e. such as the ones mentioned in Section Three) can be used.

The implementation of this Relative Distance Error Distribution will be illustrated through an example shown in Figure 11. It is when the vehicles come within detection range of a particular sensor that is of primary concern. Therefore of interest are those sample points which lie in one tail of the Relative Distance Error Distribution, which reflects the situation when the actual relative distance is less than the estimated relative distance. For this example the Relative Distance Error Distribution found for the antennas located only in the San Diego area will be used, see Figure 6.

The mean of this Relative Distance Error Distribution is so small (i.e. 3.2 yards), it is assumed for all practical purposes to be zero. As shown in Figure 11 positions (a) and (b) reflect the estimated positions of vehicles A and B respectively at time 0900. The Relative Distance Error Distribution could be superimposed over one of these positions,

Operational Flow Diagram

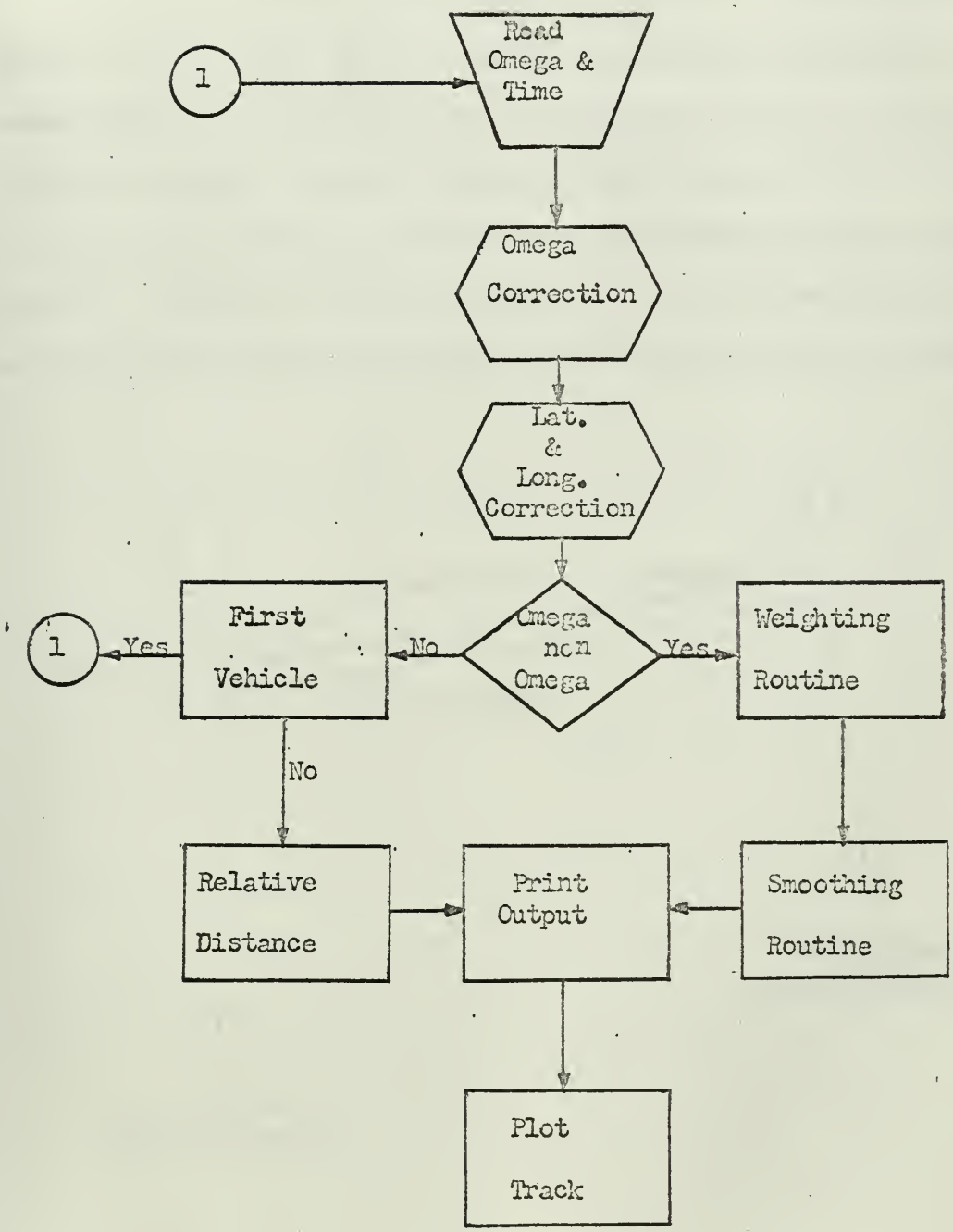


Figure #10

Use of Relative Distance Error Distribution

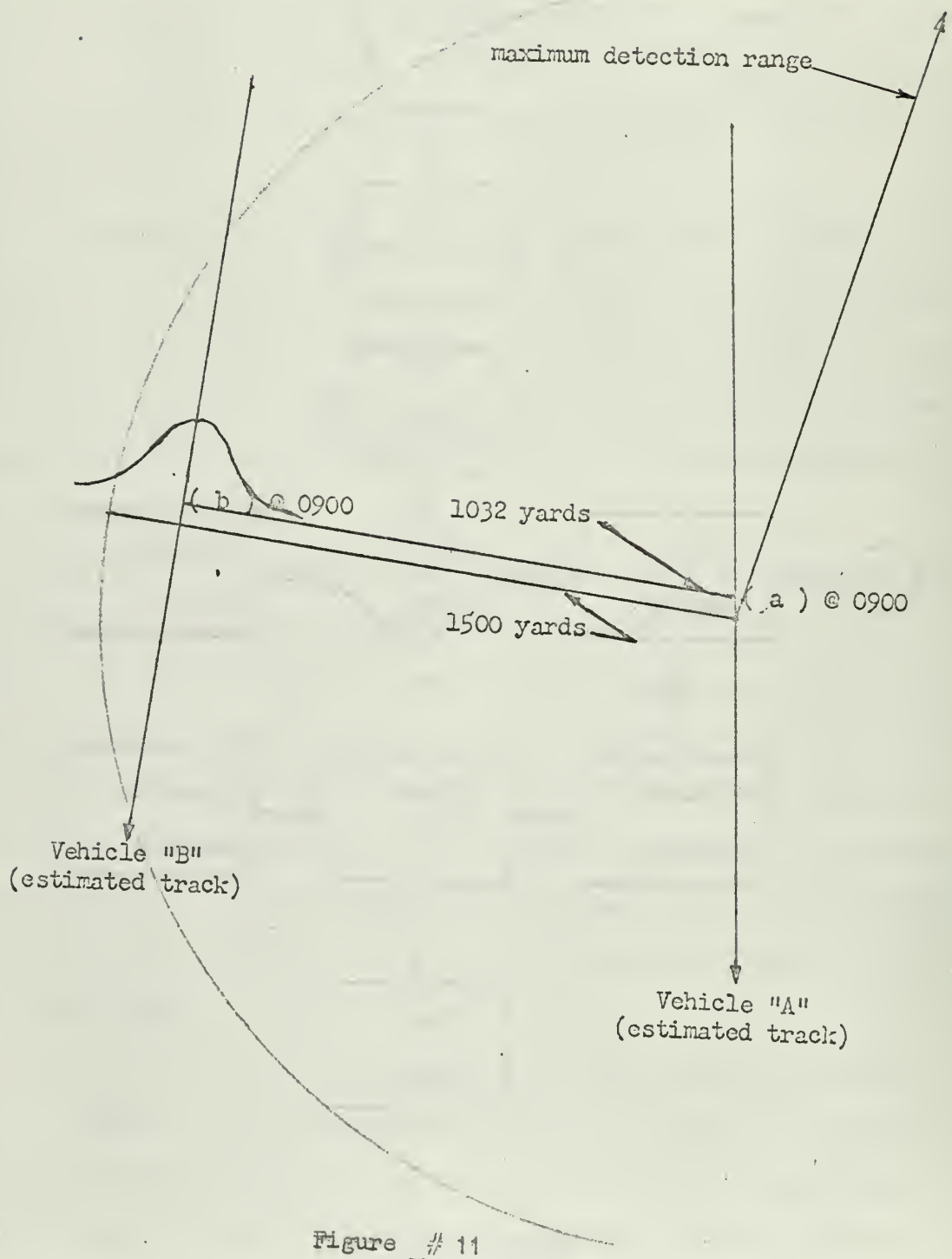


Figure # 11

say (b), with the mean situated at (b). The distribution then represents the sample points of the various estimated relative distance readings.

It may be desirable to know what the relative distance between the ships must be so that, say ten percent, of the Relative Distance Error sample points fall outside of the assumed maximum detection range of a particular sensor. For this example, relative distance between the ships is found to be - 468 yards from the maximum detection range as shown in Figure 6. Therefore as shown in Figure 11 if the maximum detection range was 1500 yards, then the estimated relative distance was 1032 yards.

Section Six

Summary

It was shown that the position coordinates for a particular vehicle can be obtained as a function of time and that a continuous track of the vehicles may be graphically displayed. This information requires less than five minutes of CDC 1604 computer time for 16 hours of continuous interplay.

A methodology for predetermining a relative distance error distribution was demonstrated and an actual distribution for the San Diego area was established. This was accomplished by using Omega navigation information collected from receiving antennas whose exact positions are known.

Attempts to smooth the vehicles estimated tracks did not improve the relative distance errors. This apparently resulted from disturbing the navigational error correlation between the vehicles. However, when absolute accuracy of navigational positions was desired (i.e. when only one vehicle was receiving Omega information) smoothing the estimated tracks was an effective feature. Improvement on the absolute accuracy was also observed when an expected estimated position was determined by using other navigational sources in conjunction with Omega.

It is recommended that in view of these desirable characteristics, that the United States Navy continue the investigation into the use of Omega triangulation information for track reconstruction techniques in ASW reconstruction sessions.

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```
      TRACK SIMULATION PROGRAM

      PROGRAM TRACK                                                    TRAC0000

      DIMENSION S1(400),S2(400),T(400),DIST(400),X(400),Y(400),ERR(400) TRAC0010

C     S1=RECEIVER ONE, S2= RECEIVER TWO, T=TIME, DIST=RELATIVE DISTANCE TRAC0020
C     BETWEEN TWO VEHICLES, X=LONGITUDE OF ESTIMATED VEHICLE POSITION   TRAC0030
C     Y=LATITUDE OF ESTIMATED VEHICLE POSITION, ERR= ERROR IN DISTANCE  TRAC0040
C      BETWEEN VEHICLES                                                 TRAC0050

      DIMENSION XPT(400),YPT(400),XXPT(400),YYPT(400),TABLE(3,3,48)     TRAC0060

C     XPT= LONGITUDE OF ESTIMATED ANTENNA POSITION, YPT LATITUDE OF ESTITRAC0070
C     MATED ANTENNA POSITION, XXPT=LONGITUDE OF ACTUAL VEHICLE POSITION TRAC0080
C     YYPT=LATITUDE OF ACTUAL VEHICLE POSITION, TABLE=OMEGA CORRECTION  TRAC0090
C     MATRIX                                                           TRAC0100

      DIMENSION XLONG(9,9),YLAT(9,9),OMEGA(2,9),YYLAT(3),XXLONG(3)      TRAC0110

C     XLONG= LONGITUDE INTERSECTION OF TWO OMEGA LANES, XLAT=LATITUDE   TRAC0120
C     INTERSECTION OF TWO OMEGA LANES, OMEGA=OMEGA VALUES AT INTERSECTIOTRAC0130
C     N, YYLAT= LATITUDE ASSOCIATED WITH CORRECTION MATRIX, XXLONG ASSOCTRAC0140
C     IATED WITH CORRECTION MATRIX                                     TRAC0150

      DIMENSION ANGLE(400),ANTDIST(400),XX(400),YY(400),SMOERR(400)     TRAC0160

C     ANGLE=ERROR BEARING FROM ANTENNA POSITION,ANTDIST=ERROR DISTANCE FTRAC0170
C     ROM ANTENNA POSITION,XX=SMOOTHED LONGITUDE OF ESTIMATED TRACK,YY=STRAC0180
C     MOOTHED LATITUDE OF ESTIMATED TRACK,SMOERR=SMOOTHED ERROR DISTANCETRAC0190
C     BETWEEN VEHICLES                                                 TRAC0200

      DIMENSION Z(200),ZZ(200),W(200),WW(200),P(200),V(200),IT(12)      TRAC0210

      DIMENSION XT(35),YT(35),ZT(35),WT(35),DX(10),DY(10)               TRAC0220
```

```
C     Z,ZZ,W,WW,P,V,IT,XT,YT,ZT,WT,DX,DY = PLOT ROUTINE STORAGE          TRAC0230

C     L= VEHICLE STARTING INDEX, K1=NUMBER OF POSITION POINTS FOR EACH   TRAC0240
C     VEHICLE                                                            TRAC0250

      L=L+1                                                              TRAC0260
      READ 5,L,K1,(((TABLE(I,J,K),K=1,48),J=1,3),I=1,3)                  TRAC0270
    5 FORMAT(2I3/(16F4.2))                                               TRAC0280
      READ 6,YYLAT,XXLONG                                                TRAC0290
    6 FORMAT(6F5.2)                                                      TRAC0300
   21 READ 10,((XLONG(I,J),J=1,3),I=1,3)                                 TRAC0310
   10 FORMAT(9F7.3)                                                      TRAC0320
      READ 11,((YLAT(I,J),J=1,3),I=1,3)                                  TRAC0330
   11 FORMAT(9F7.3)                                                      TRAC0340
      READ 12,((OMEGA(I,J),J=1,3),I=1,2)                                 TRAC0350
   12 FORMAT(6F7.0)                                                      TRAC0360
      READ 22,ANTLAT,ANTLONG                                             TRAC0370
   22 FORMAT(2F10.5)                                                     TRAC0380
      READ 17,(XXPT(I),YYPT(I),I=L,K1)                                   TRAC0390
   17 FORMAT(8F10.5)                                                     TRAC0400
      READ 15,(S1(I),T(I),S2(I),I=L,K1)                                  TRAC0410
   15 FORMAT(6F10.3)                                                     TRAC0420
      READ 18,L3,FIXLAT,FIXLONG                                          TRAC0430

C     FIXLONG = EXPECTED LONGITUDE, FIXLAT = EXPECTED LATITUDE           TRAC0440

   18 FORMAT(I5,2F10.5)                                                  TRAC0450
      DO 16 I=L,K1                                                       TRAC0460

C     CORRECTION CONVERSION ROUTINE                                      TRAC0470

C     ANTLAT=ANTENNA LATITUDE, ANTLONG= ANTENNA LONGITUDE                TRAC0480

      YDIFF= ANTLAT - YYLAT(2)                                           TRAC0490
      IF(YDIFF)25,25,30                                                  TRAC0500
   25 N1=1                                                               TRAC0510
```

```
      GO TO 35                                                          TRAC0520
   30 N1=2                                                              TRAC0530
   35 XDIFF= ANTLONG - XXLONG(2)                                        TRAC0540
      IF(XDIFF)40,40,45                                                 TRAC0550
   40 N2=1                                                              TRAC0560
      GO TO 47                                                          TRAC0570
   45 N2=2                                                              TRAC0580
   47 N3=XINTF(T(I))                                                    TRAC0590
      IF(N3.EQ.0)50,55                                                  TRAC0600
   50 N3=24                                                             TRAC0610
   55 W3=FLOATF(N3)                                                     TRAC0620
      VALUE1=TABLE(N1,N2,N3)                                            TRAC0630
      N1=N1+1                                                           TRAC0640

C     INTERNATIONAL DATE LINE AND EQUATOR TRANSITIONS NOT CONSIDERED    TRAC0650

      VALUE2=TABLE(N1,N2,N3)                                            TRAC0660
      XINEAR1=VALUE2+((VALUE2-VALUE1)*YDIFF/1.4)                        TRAC0670
      N2=N2+1                                                           TRAC0680
      VALUE2=TABLE(N1,N2,N3)                                            TRAC0690
      N1=N1-1                                                           TRAC0700
      VALUE1=TABLE(N1,N2,N3)                                            TRAC0710
      XINEAR2=VALUE2+((VALUE2-VALUE1)*YDIFF/1.4)                        TRAC0720
      IF(N2.EQ.2)58,59                                                  TRAC0730
   58 XINEAR3=XINEAR2+((XINEAR2-XINEAR1)*XDIFF/1.9)                     TRAC0740
      GO TO 158                                                         TRAC0750
   59 XINEAR3=XINEAR1+((XINEAR2-XINEAR1)*XDIFF/1.9)                     TRAC0760
  158 N3=N3+1                                                           TRAC0770
      IF(N3.EQ.25)60,65                                                 TRAC0780
   60 N3=1                                                              TRAC0790
   65 VALUE3=TABLE(N1,N2,N3)                                            TRAC0800
      TDIFF=VALUE3-VALUE1                                               TRAC0810
      SUB=T(I)-W3                                                       TRAC0820
      XINEAR4=XINEAR3+(SUB/.6)*TDIFF                                    TRAC0830
      N2=N2-1                                                           TRAC0840
      IF(N3.EQ.1)1,2                                                    TRAC0850
```

```
    1 N3 = 48                                                              TRAC0860
      GO TO 3                                                              TRAC0870
    2 N3 = N3+23                                                           TRAC0880
    3 VALUE1=TABLE(N1,N2,N3)                                               TRAC0890
      N1=N1+1                                                              TRAC0900
      VALUE2=TABLE(N1,N2,N3)                                               TRAC0910
      XINEAR1=VALUE2+((VALUE2-VALUE1)*YDIFF/1.4)                           TRAC0920
      N2=N2+1                                                              TRAC0930
      VALUE2=TABLE(N1,N2,N3)                                               TRAC0940
      N1=N1-1                                                              TRAC0950
      VALUE1=TABLE(N1,N2,N3)                                               TRAC0960
      XINEAR2=VALUE2+((VALUE2-VALUE1)*YDIFF/1.4)                           TRAC0970
      IF(N2.EQ.2)66,67                                                     TRAC0980
   66 XINEAR3=XINEAR2+((XINEAR2-XINEAR1)*XDIFF/4.0)                        TRAC0990
      GO TO 68                                                             TRAC1000
   67 XINEAR3=XINEAR1+((XINEAR2-XINEAR1)*XDIFF/1.9)                        TRAC1010
   68 N3=N3+1                                                              TRAC1020
      IF(N3.EQ.49)70,75                                                    TRAC1030
   70 N3=25                                                                TRAC1040
   75 VALUE3=TABLE(N1,N2,N3)                                               TRAC1050
      TDIFF=VALUE3-VALUE1                                                  TRAC1060
      XINEAR5=XINEAR3+(SUB/.6)*TDIFF                                       TRAC1070
      S1(I)=S1(I)-XINEAR4                                                  TRAC1080
      S2(I)=S2(I)-XINEAR5                                                  TRAC1090

C     OMEGA LATITUDE AND LONGTUDE CONVERSION AT ANTENNA LOCATION ROUTINE   TRAC1100

      ALFA1=1.0+S1(I)-OMEGA(1,1)                                           TRAC1110
      N1=XINTF(ALFA1)                                                      TRAC1120
      L1=XINTF(ALFA1+.5)                                                   TRAC1130
      ALFA2=1.0+S2(I)-OMEGA(2,1)                                           TRAC1140
      N2=XINTF(ALFA2)                                                      TRAC1150
      L2=XINTF(ALFA2+.5)                                                   TRAC1160
      DELTA1=OMEGA(1,L1+1)-OMEGA(1,L1)                                     TRAC1170
      DELTA2=OMEGA(2,L2+1)-OMEGA(2,L2)                                     TRAC1180
      DELTA3=S1(I)-OMEGA(1,N1)                                             TRAC1190
```

```
      DELTA4=S2(I)-OMEGA(2,N2)                                          TRAC1200
      YPT(I)=YLAT(N1,N2)+(YLAT(L1+1,L2)-YLAT(L1,L2))*DELTA3/DELTA1+(YLATTRAC1210
     1(L1,L2+1)-YLAT(L1,L2))*DELTA4/DELTA2                              TRAC1220
      XPT(I)=XLONG(N1,N2)+(XLONG(L1+1,L2)-XLONG(L1,L2))*DELTA3/DELTA1+(XTRAC1230
     1LONG(L1,L2+1)-XLONG(L1,L2))*DELTA4/DELTA2                         TRAC1240

C     ANTENNA ERROR FACTOR ROUTINE                                      TRAC1250

      DIFLAT = ANTLAT -  YPT(I)                                         TRAC1260
      DIFLONG = ANTLONG - XPT(I)                                        TRAC1270
      ANTDIST(I)=SQRTF(DIFLAT*DIFLAT+DIFLONG*DIFLONG)                   TRAC1280
      ANGLE(I) = ATANF(DIFLAT/DIFLONG)*57.29                            TRAC1290

C     VEHICLE TRACK SIMULATION ROUTINE                                  TRAC1300

      Y(I) = YYPT(I)+DIFLAT                                             TRAC1310
      X(I) = XXPT(I)+DIFLONG                                            TRAC1320
   16 CONTINUE                                                          TRAC1330

C     EXPECTED POSITION ROUTINE                                         TRAC1340

      IF(L3.EQ.0)76,74                                                  TRAC1350
   74 XP= FIXLONG-X(L3)                                                 TRAC1360
      YP = FIXLAT -Y(L3)                                                TRAC1370
      XX(L)= X(L)+XP                                                    TRAC1380
      YY(L) = Y(L)+YP                                                   TRAC1390
      L1 = L+1                                                          TRAC1400

C     EXPONENTIAL SMOOTHING ROUTINE                                     TRAC1410

      DO 100 I = L1,K1                                                  TRAC1420
      XX(I) = .4*(X(I)+XP) +.6*XX(I-1)                                  TRAC1430
      YY(I) = .4*(Y(I)+YP) +.6*YY(I-1)                                  TRAC1440
  100 CONTINUE                                                          TRAC1450

C     READ IN SECOND VEHICLE DATA                                       TRAC1460
```

```
   76 IF(L-1)77,77,79                                                    TRAC1470
   77 L = 201                                                            TRAC1480
      K1= K1+200                                                         TRAC1490
      GO TO 21                                                           TRAC1500
   79 L = 1                                                              TRAC1510
      K1 = K1-200                                                        TRAC1520
      DO 120 I=1,K1                                                      TRAC1530
C     RELATIVE DISTANCE BETWEEN ACTUAL VEHICLE POSITIONS ROUTINE         TRAC1540
      ACTDIST=SQRTF((XXPT(I)-XXPT(I+200))*(XXPT(I)-XXPT(I+200))+(YYPT(I)TRAC1550
     1-YYPT(I+200))*(YYPT(I)-YYPT(I+200)))                               TRAC1560
C     RELATIVE DISTANCE BETWEEN ESTIMATED VEHICLE POSITIONS ROUTINE      TRAC1570
      ESTDIST=SQRTF((X(I)-X(I+200))*(X(I)-X(I+200))+(Y(I)-Y(I+200))*(Y( TRAC1580
     11)-Y(I+200)))                                                      TRAC1590
      SMODIST = SQRTF((XX(I)-XX(I+200))*(XX(I)-XX(I+200))+(YY(I)-YY(I+20TRAC1600
     10))*(YY(I)-YY(I+200)))                                             TRAC1610
C     ERROR ROUTINE                                                      TRAC1620
      ERR(I)=ACTDIST-ESTDIST                                             TRAC1630
      SMOERR(I)=ACTDIST-SMODIST                                          TRAC1640
  120 CONTINUE                                                           TRAC1650
      PRINT 84                                                           TRAC1660
   84 FORMAT(1H120X19HANTENNA OUTPUT DATA///)                            TRAC1670
      PRINT 80                                                           TRAC1680
   80 FORMAT(25X9HANTENNA A//)                                           TRAC1690
      PRINT 85                                                           TRAC1700
   85 FORMAT(05X2HS1,8X2HS26X5HANGLE5X7HANTDIST5X3HXPT7X3HYPT//)         TRAC1710
      PRINT 90,(S1(I),S2(I),ANGLE(I),ANTDIST(I),XPT(I),YPT(I),I=L,K1)    TRAC1720
   90 FORMAT(6F10.5)                                                     TRAC1730
      L=201                                                              TRAC1740
      K1=K1+200                                                          TRAC1750
      PRINT 81                                                           TRAC1760
   81 FORMAT(//25X9HANTENNA B//)                                         TRAC1770
      PRINT 91,(S1(I),S2(I),ANGLE(I),ANTDIST(I),XPT(I),YPT(I),I=L,K1)    TRAC1780
   91 FORMAT(6F10.5)                                                     TRAC1790
```

```
      PRINT 92                                                          TRAC1800
   92 FORMAT(1H115X28HTRACK SIMULATION OUTPUT DATA///)                  TRAC1810
      PRINT 89                                                          TRAC1820
   89 FORMAT(24X11HVEHICLE ONE//)                                       TRAC1830
      PRINT 93                                                          TRAC1840
   93 FORMAT(4X1HX9X1HY8X3HERR8X2HXX8X2HYY5X6HSMOERR)                   TRAC1850
      K1=K1-200                                                         TRAC1860
      L=1                                                               TRAC1870
      PRINT 94,(X(I),Y(I),ERR(I),XX(I),YY(I),SMOERR(I),I=L,K1)          TRAC1880
   94 FORMAT(6F10.5)                                                    TRAC1890
      PRINT 96                                                          TRAC1900
   96 FORMAT(//24X11HVEHICLE TWO//)                                     TRAC1910
   97 FORMAT(4X1HX9X1HY8X1HT9X2HXX8X2HYY)                               TRAC1920
      PRINT 97                                                          TRAC1930
      L=201                                                             TRAC1940
      K1=K1+200                                                         TRAC1950
      PRINT 98,(X(I),Y(I),T(I),XX(I),YY(I),I=L,K1)                      TRAC1960
   98 FORMAT(5F10.5)                                                    TRAC1970
      L=1                                                               TRAC1980
      K1=K1-200                                                         TRAC1990

C     TRACK PLOTTING ROUTINE                                            TRAC2000

      DO 105 I=1,K1                                                     TRAC2010
      XXPT(I) = -XXPT(I)+117.6                                          TRAC2020
      YYPT(I) = YYPT(I)-32.47                                           TRAC2030
      X(I) = -X(I)+117.6                                                TRAC2040
      Y(I) = Y(I)-32.47                                                 TRAC2050
      XX(I) = -XX(I)+117.6                                              TRAC2060
      YY(I) = YY(I)-32.47                                               TRAC2070
      P(I) = -XXPT(I+200) +117.6                                        TRAC2080
      V(I)=YYPT(I+200)-32.47                                            TRAC2090
      Z(I) = -X(I+200) +117.6                                           TRAC2100
      W(I)=Y(I+200)-32.47                                               TRAC2110
      ZZ(I) = -XX(I+200)+117.6                                          TRAC2120
      WW(I)=YY(I+200)-32.47                                             TRAC2130
```

```
105 CONTINUE                                                    TRAC2140
    M1 = 16                                                     TRAC2150
    J = 1                                                       TRAC2160
    DO 110 I = 1,M1                                             TRAC2170
    XT(I) = X(J)                                                TRAC2180
    YT(I) = Y(J)                                                TRAC2190
    WT(I) = W(J)                                                TRAC2200
    ZT(I) = Z(J)                                                TRAC2210
    J = J+4                                                     TRAC2220
110 CONTINUE                                                    TRAC2230
    LAB1=4HACT1                                                 TRAC2240
    LAB2 = 8HEST1EST1                                           TRAC2250
    LAB3=4HSMO1                                                 TRAC2260
    LAB4=4HACT2                                                 TRAC2270
    LAB5 = 8HEST2EST2                                           TRAC2280
    LAB6=4HSMO2                                                 TRAC2290
    LAB7 = 8HNE  SW                                             TRAC2300
    IT(1)=8HAVTOMATI                                            TRAC2310
    IT(2)=8HC TRACK                                             TRAC2320
    IT(3)=8HRECONSTR                                            TRAC2330
    IT(4)=8HUCTION O                                            TRAC2340
    IT(5)=8HF TWO AS                                            TRAC2350
    IT(6)=8HW CRAFT                                             TRAC2360
    IT(7)=8HLT. R.A.                                            TRAC2370
    IT(8)=8HGARRETT                                             TRAC2380
    IT(9)=8H                                                    TRAC2390
    IT(10)=8H                                                   TRAC2400
    IT(11)=8H                                                   TRAC2410
    IT(12)=8H                                                   TRAC2420
    MM = 4                                                      TRAC2430
    DX(1) = -0.0                                                TRAC2440
    DX(2) = -0.4                                                TRAC2450
    DX(3) = -0.0                                                TRAC2460
    DX(4) = -0.4                                                TRAC2470
    DY(1) = 0.1                                                 TRAC2480
    DY(2) = 0.1                                                 TRAC2490
```

```
      DY(3) = 0.0                                                                    TRAC2500
      DY(4) = 0.0                                                                    TRAC2510
      CALL DRAW(MM,DX,DY,1,1,LAB7,IT,0,0,0,8,0,2,8,8,1,LAST)                         TRAC2520
      CALL DRAW(K1,XXPT,YYPT,2,0,LAB1,IT,0,0,0,0,0,0,8,8,0,LAST)                     TRAC2530
      CALL DRAW(M1,XT,YT,2,4,LAB2,IT,0,0,0,0,0,0,8,8,0,LAST)                         TRAC2540
      CALL DRAW(K1,XX,YY,2,0,LAB3,IT,0,0,0,0,0,0,8,8,0,LAST)    C                    TRAC2550
      CALL DRAW(K1,P,V,2,0,LAB4,IT,0,0,0,0,0,0,8,8,0,LAST)                           TRAC2560
      CALL DRAW(M1,ZT,WT,2,4,LAB5,IT,0,0,0,0,0,0,8,8,0,LAST)                         TRAC2570
      CALL DRAW(K1,ZZ,WW,3,0,LAB6,IT,0,0,0,0,0,0,8,8,0,LAST)                         TRAC2580
      END                                                                            TRAC2590
```

ANTENNA OUTPUT DATA

ANTENNA A

S1	S2	ANGLE	ANTDIST	XPT	YPT
269.97600	102.07000	66.47714	.03170	117.25386	32.73384
269.97567	102.06983	66.43310	.03176	117.25390	32.73388
269.98333	102.08467	63.84887	.02776	117.25344	32.72969
270.00500	102.11450	60.73126	.01893	117.25046	32.72128
270.04667	102.08933	87.81616	.02398	117.24212	32.72873
270.00833	102.07017	77.90167	.02988	117.24747	32.73398
270.00000	102.06900	75.57103	.03046	117.24879	32.73427
269.99167	102.06783	71.58217	.03159	117.25112	32.73455
269.98133	102.06767	68.65301	.03196	117.25284	32.73454
269.97500	102.06750	66.93008	.03236	117.25389	32.73454
269.97667	102.06733	67.43927	.03230	117.25360	32.73460
269.97833	102.06817	67.66687	.03200	117.25337	32.73437
269.98000	102.07800	65.13051	.02954	117.25363	32.73157
269.98167	102.07283	67.25242	.03067	117.25307	32.73306
269.96533	102.06867	63.95451	.03276	117.25557	32.73415
269.96300	102.06850	63.38494	.03290	117.25595	32.73419
269.96467	102.06833	63.87865	.03283	117.25566	32.73424
269.96033	102.06817	62.78684	.03317	117.25637	32.73427
269.96000	102.06800	62.75153	.03323	117.25642	32.73431
269.96067	102.06783	62.97709	.03322	117.25630	32.73436
269.95333	102.06567	61.76671	.03424	117.25741	32.73494
269.93700	102.06650	57.54507	.03535	117.26018	32.73460
269.94167	102.06633	58.70073	.03500	117.25939	32.73468
269.95333	102.06617	61.61251	.03413	117.25743	32.73480
269.96200	102.06600	63.88217	.03355	117.25598	32.73490
269.96667	102.06583	65.15846	.03328	117.25519	32.73497
269.96833	102.06667	65.55845	.03297	117.25496	32.73474
269.97000	102.06650	65.85524	.03291	117.25467	32.73480
269.95667	102.06433	63.01080	.03431	117.25678	32.73534
269.95833	102.06417	63.48344	.03423	117.25649	32.73540
269.96000	102.06500	63.66271	.03392	117.25626	32.73517
269.96167	102.06483	64.14218	.03384	117.25597	32.73523
269.96333	102.06567	64.32952	.03354	117.25574	32.73500
269.96000	102.06450	63.81096	.03404	117.25623	32.73531
269.96167	102.06433	64.28911	.03396	117.25594	32.73537
269.96333	102.06417	64.76932	.03389	117.25565	32.73543
269.96500	102.06400	65.25152	.03382	117.25537	32.73549
269.96667	102.06283	66.01821	.03399	117.25502	32.73583
269.96833	102.06167	66.77706	.03417	117.25468	32.73617
269.97700	102.06150	69.11894	.03372	117.25322	32.73627
269.97667	102.06333	68.54440	.03328	117.25338	32.73575
269.96333	102.06317	65.05747	.03413	117.25560	32.73571
269.96500	102.06300	65.53690	.03406	117.25531	32.73577
269.96767	102.06783	64.83302	.03274	117.25513	32.73441
269.97333	102.06767	66.42274	.03242	117.25418	32.73449
269.97500	102.06250	68.31764	.03358	117.25361	32.73598
269.97867	102.06233	69.35188	.03342	117.25299	32.73604
269.98333	102.06217	70.67046	.03322	117.25220	32.73612
269.98000	102.06300	69.54122	.03318	117.25281	32.73586
269.97067	102.06283	67.07096	.03375	117.25435	32.73585
269.96333	102.06267	65.20005	.03424	117.25557	32.73586
269.96500	102.06250	65.67810	.03418	117.25528	32.73591
269.97667	102.06133	69.07285	.03378	117.25327	32.73632
269.97133	102.06117	67.69935	.03411	117.25415	32.73633
269.97200	102.06100	67.91949	.03412	117.25403	32.73639
269.97367	102.06083	68.40403	.03406	117.25374	32.73644
269.97533	102.06267	68.36267	.03352	117.25557	32.73593
269.97600	102.06250	68.58665	.03352	117.25345	32.73598
269.97467	102.06033	68.79965	.03413	117.25355	32.73659
269.97033	102.06017	67.70366	.03442	117.25426	32.73661
269.97000	102.06000	67.66095	.03448	117.25431	32.73666

ANTENNA B

269.98500	102.08300	64.96593	.02803	117.25307	32.73017
269.98167	102.07283	67.25242	.03067	117.25307	32.73306
269.98533	102.08967	62.61072	.02646	117.25338	32.72827
270.00000	102.07950	72.86857	.02772	117.24937	32.73126
270.01667	102.08433	77.37110	.02583	117.24685	32.72998
269.99633	102.06917	72.61955	.03083	117.25042	32.73420
269.99600	102.06400	73.79251	.03218	117.25019	32.73567
269.99767	102.06883	73.10381	.03086	117.25018	32.73430
269.98333	102.06867	68.94338	.03160	117.25256	32.73426
269.97000	102.06850	65.26473	.03243	117.25478	32.73423
269.97167	102.06833	65.76965	.03237	117.25449	32.73429
269.97333	102.08317	61.33788	.02881	117.25503	32.73005
269.97500	102.07800	63.65325	.02987	117.25447	32.73154
269.97667	102.08783	60.57341	.02752	117.25473	32.72874
269.95333	102.07767	57.76717	.03161	117.25807	32.73151
269.95500	102.05750	64.55289	.03601	117.25668	32.73729
269.96467	102.08733	57.19280	.02860	117.25670	32.72881
269.97333	102.07717	63.45005	.03018	117.25476	32.73177
269.95000	102.07200	58.88602	.03310	117.25831	32.73311
269.95667	102.07183	60.65441	.03261	117.25719	32.73320
269.95333	102.07667	58.12554	.03182	117.25801	32.73179
269.91500	102.07650	49.16573	.03547	117.26445	32.73161
269.94167	102.06633	58.70073	.03500	117.25939	32.73468
269.94833	102.07617	57.71659	.03235	117.25882	32.73191
269.96500	102.07600	61.49217	.03105	117.25603	32.73205
269.96667	102.06583	65.15846	.03328	117.25519	32.73497
269.96833	102.06567	65.65032	.03321	117.25490	32.73503
269.97700	102.07550	65.96106	.03033	117.25399	32.73227
269.94167	102.06533	59.01885	.03522	117.25934	32.73496
269.94333	102.06517	59.46938	.03512	117.25905	32.73502
269.97000	102.07000	64.81040	.03208	117.25486	32.73380
269.95667	102.07383	59.98442	.03217	117.25730	32.73262
269.95833	102.06667	62.73062	.03365	117.25663	32.73468
269.95500	102.06850	61.30366	.03348	117.25728	32.73414
269.95167	102.07633	57.81118	.03203	117.25627	32.73188
269.96033	102.06417	63.99473	.03409	117.25615	32.73541
269.96500	102.07600	61.49218	.03105	117.25603	32.73205
269.96667	102.06383	65.73567	.03375	117.25508	32.73554
269.97033	102.06367	66.75164	.03357	117.25446	32.73561
269.97700	102.06350	68.59023	.03322	117.25335	32.73570
269.98867	102.07533	68.58742	.02966	117.25204	32.73239
269.95833	102.06517	63.77751	.03446	117.25643	32.73568
269.95500	102.06500	62.38934	.03427	117.25709	32.73514
269.95867	102.07483	60.17285	.03179	117.25702	32.73255
269.96533	102.06267	65.71769	.03412	117.25524	32.73587
269.96500	102.06450	65.10733	.03370	117.25539	32.73534
269.97667	102.07933	63.69012	.02945	117.25426	32.73117
269.98833	102.06717	70.78826	.03172	117.25164	32.73472
269.98000	102.07200	67.01907	.03097	117.25338	32.73329
269.96667	102.06383	65.73567	.03375	117.25508	32.73554
269.95633	102.06667	62.21799	.03380	117.25696	32.73467
269.95700	102.06350	63.34234	.03447	117.25667	32.73558
269.97667	102.07133	66.26560	.03134	117.25382	32.73346
269.98333	102.07917	65.75168	.02905	117.25314	32.73126
269.96200	102.07800	59.97108	.03083	117.25664	32.73146
269.96867	102.07283	64.18718	.03197	117.25513	32.73355
269.91333	102.07067	50.90792	.03672	117.26436	32.73327
269.96600	102.06550	65.07949	.03340	117.25528	32.73506
269.96667	102.06033	66.70747	.03459	117.25489	32.73654
269.96833	102.06017	67.18341	.03453	117.25460	32.73660
269.97000	102.07000	64.81040	.03208	117.25486	32.73383

TRACK SIMULATION OUTPUT DATA

VEHICLE ONE

X	Y	ERR	XX	YY	SMOERR
117.98735	32.48793	.00035	117.98735	32.48793	.00035
117.98231	32.48789	.00074	117.98533	32.48792	-.00307
117.97577	32.49208	-.00011	117.98151	32.48958	-.00844
117.97275	32.50049	.00208	117.97800	32.49395	-.00835
117.97409	32.49304	-.00454	117.97644	32.49358	-.01218
117.96174	32.48779	-.00290	117.97056	32.49126	-.01381
117.95442	32.48750	-.00119	117.96410	32.48976	-.01292
117.94709	32.48722	.00090	117.95730	32.48874	-.01154
117.93837	32.48723	.00023	117.94973	32.48814	-.01216
117.93032	32.48722	-.00093	117.94196	32.48777	-.01359
117.92361	32.48717	-.00093	117.93462	32.48753	-.01384
117.91284	32.48740	-.00246	117.92591	32.48748	-.01633
117.90558	32.49020	-.00083	117.91778	32.48857	-.01543
117.90014	32.48871	-.00256	117.91072	32.48862	-.01494
117.89264	32.48762	-.00302	117.90349	32.48822	-.01426
117.88526	32.48758	-.00003	117.89620	32.48797	-.01442
117.87855	32.48753	-.00248	117.88914	32.48779	-.01420
117.87284	32.48750	.00091	117.88262	32.48768	-.01217
117.86679	32.48746	-.00216	117.87629	32.48759	-.01276
117.85991	32.48741	-.00121	117.86974	32.48752	-.01269
117.85180	32.48683	-.00171	117.86256	32.48724	-.01330
117.84303	32.48717	-.00505	117.85475	32.48721	-.01386
117.83882	32.48709	0	117.84838	32.48716	-.01212
117.83378	32.48697	-.00265	117.84254	32.48709	-.01401
117.82823	32.48687	-.00168	117.83682	32.48700	-.01288
117.82402	32.48680	0	117.83170	32.48692	-.01090
117.81625	32.48703	.00025	117.82552	32.48696	-.01030
117.81154	32.48697	-.00194	117.81993	32.48697	-.00874
117.80243	32.48643	-.00102	117.81293	32.48675	-.00675
117.79672	32.48637	-.00045	117.80645	32.48660	-.00347
117.79195	32.48660	-.00172	117.80065	32.48667	-.00010
117.78524	32.48654	-.00159	117.79449	32.48658	.00298
117.77847	32.48677	.00036	117.78808	32.48665	.00622
117.77298	32.48646	.00002	117.78204	32.48658	.00758
117.76727	32.48640	-.00027	117.77613	32.48650	.00870
117.76056	32.48634	.00043	117.76990	32.48644	.01114
117.75384	32.48628	-.00098	117.76348	32.48638	.01237
117.74819	32.48594	-.00006	117.75736	32.48620	.01201
117.74353	32.48560	-.00041	117.75183	32.48596	.01107
117.73799	32.48550	-.00009	117.74629	32.48577	.01121
117.73083	32.48602	-.00233	117.74011	32.48587	.01096
117.72261	32.48606	.00079	117.73311	32.48595	.01230
117.71690	32.48600	.00153	117.72663	32.48597	.01221
117.71108	32.48736	.00126	117.72041	32.48653	.01189
117.70503	32.48728	.00136	117.71426	32.48683	.01355
117.69860	32.48579	.00158	117.70799	32.48642	.01416
117.69322	32.48573	.00005	117.70208	32.48614	.01333
117.68801	32.48565	-.00085	117.69645	32.48594	.01177
117.68041	32.48591	-.00010	117.69003	32.48593	.01197
117.67486	32.48692	.00064	117.68396	32.48632	.01097
117.66764	32.49091	.00113	117.67743	32.48816	.01093
117.66293	32.49386	.00131	117.67163	32.49044	.01053
117.66094	32.49745	.00007	117.66735	32.49324	.00902
117.65706	32.50144	-.00180	117.66324	32.49652	.00689
117.65518	32.50738	.00192	117.66001	32.50087	.00639
117.65447	32.51333	.00108	117.65779	32.50585	.00521
117.65464	32.51884	.01052	117.65653	32.51105	.00783
117.65476	32.52479	.00178	117.65583	32.51654	.00353
117.65466	32.52818	.00133	117.65536	32.52120	.00264
117.65395	32.53316	.00033	117.65479	32.52598	.00351
117.65393	32.53811	.00050	117.65444	32.53083	.00290

VEHICLE TWO

X	Y	T	XX	YY
117.74514	32.51860	17.00000	117.74514	32.51860
117.74614	32.51571	17.01000	117.74554	32.51744
117.74983	32.52050	17.02000	117.74726	32.51867
117.75484	32.51751	17.03000	117.75029	32.51820
117.75936	32.51879	17.04000	117.75392	32.51844
117.75779	32.51457	17.05000	117.75547	32.51689
117.75902	32.51310	17.06000	117.75689	32.51537
117.76103	32.51447	17.07000	117.75855	32.51501
117.76065	32.51451	17.08000	117.75939	32.51481
117.76143	32.51454	17.09000	117.76021	32.51470
117.76372	32.51448	17.10000	117.76161	32.51462
117.76418	32.51872	17.11000	117.76264	32.51626
117.76674	32.51723	17.12000	117.76428	32.51664
117.76848	32.52003	17.13000	117.76596	32.51800
117.76714	32.51726	17.14000	117.76644	32.51770
117.77153	32.51148	17.15000	117.76847	32.51522
117.77251	32.51996	17.16000	117.77009	32.51711
117.77651	32.51700	17.17000	117.77266	32.51707
117.77490	32.51566	17.18000	117.77355	32.51651
117.77702	32.51557	17.19000	117.77494	32.51613
117.77820	32.51698	17.20000	117.77624	32.51647
117.77281	32.51716	17.21000	117.77487	32.51675
117.77982	32.51409	17.22000	117.77685	32.51568
117.78439	32.51686	17.23000	117.77987	32.51616
117.78818	32.51672	17.24000	117.78319	32.51638
117.79102	32.51380	17.25000	117.78633	32.51535
117.79331	32.51574	17.26000	117.78912	32.51470
117.79722	32.51650	17.27000	117.79236	32.51542
117.79387	32.51381	17.28000	117.79296	32.51478
117.79516	32.51375	17.29000	117.79384	32.51436
117.80135	32.51497	17.30000	117.79685	32.51461
117.80091	32.51615	17.31000	117.79847	32.51522
117.80258	32.51409	17.32000	117.80012	32.51477
117.80393	32.51463	17.33000	117.80164	32.51471
117.80494	32.51689	17.34000	117.80296	32.51558
117.81006	32.51336	17.35000	117.80580	32.51469
117.81318	32.51872	17.36000	117.80875	32.51630
117.81613	32.51523	17.37000	117.81171	32.51587
117.81875	32.51516	17.38000	117.81452	32.51559
117.82088	32.51507	17.39000	117.81707	32.51538
117.82417	32.51838	17.40000	117.81991	32.51658
117.82278	32.51609	17.41000	117.82106	32.51638
117.82312	32.51763	17.42000	117.82188	32.51688
117.82419	32.52042	17.43000	117.82281	32.51830
117.82897	32.51690	17.44000	117.82527	32.51774
117.83082	32.51843	17.45000	117.82749	32.51801
117.83395	32.52360	17.46000	117.83007	32.52025
117.83757	32.52105	17.47000	117.83307	32.52017
117.83691	32.52348	17.48000	117.83461	32.52149
117.83715	32.52223	17.49000	117.83562	32.52179
117.83625	32.52510	17.50000	117.83587	32.52311
117.83754	32.52619	17.51000	117.83654	32.52434
117.84139	32.52931	17.52000	117.83848	32.52633
117.84307	32.53351	17.53000	117.84032	32.52920
117.84057	32.53531	17.54000	117.84042	32.53164
117.84308	32.53422	17.55000	117.84148	32.53267
117.83485	32.53650	17.56000	117.83883	32.53420
117.84093	32.53671	17.57000	117.83967	32.53521
117.84132	32.53623	17.58000	117.84033	32.53561
117.84461	32.53817	17.59000	117.84204	32.53664
117.84535	32.54297	18.00000	117.84337	32.53917

```
      TRACK OPERATIONAL PROGRAM

      PROGRAM TRACK                                                    TRAC0000

      DIMENSION S1(1000),S2(1000),T(1000),DIST(500),X(1000),Y(1000)    TRAC0010

C     S1=RECEIVER ONE, S2= RECEIVER TWO, T=TIME, DIST=RELATIVE DISTANCE TRAC0020
C     BETWEEN TWO VEHICLES, X=LONGITUDE OF ESTIMATED VEHICLE POSITION  TRAC0030
C     Y=LATITUDE OF ESTIMATED VEHICLE POSITION                         TRAC0040

      DIMENSION XLONG(9,9),YLAT(9,9),OMEGA(2,9),YYLAT(3),XXLONG(3)     TRAC0050

C     XLONG= LONGITUDE INTERSECTION OF TWO OMEGA LANES, XLAT=LATITUDE  TRAC0060
C     INTERSECTION OF TWO OMEGA LANES, OMEGA=OMEGA VALUES AT INTERSECTIOTRAC0070
C     N, YYLAT= LATITUDE ASSOCIATED WITH CORRECTION MATRIX, XXLONG ASSOCTRAC0080
C     IATED WITH CORRECTION MATRIX                                     TRAC0090
C     ADJUST CONVERSION MATRIX INFORMATION TO COVER AREA OF INTEREST   TRAC0100

      DIMENSION TABLE(3,3,48),Z(500),W(533)                            TRAC0110

C     TABLE=OMEGA CORRECTION MATRIX, Z AND W PLOT ROUTINE STORAGE      TRAC0120

      DIMENSION DX(10),DY(10),A(100),B(100),C(100),D(100),IT(12)       TRAC0130

C     DX,DY,A,B,C,D,IT = PLOT ROUTINE STORAGE                          TRAC0140
C     L= VEHICLE STARTING INDEX, K1=NUMBER OF POSITION POINTS FOR EACH TRAC0150
C     VEHICLE                                                          TRAC0160
C     SUFFICIENT OMEGA CORRECTION INFORMATION FOR 500 SQUARE MILE AREA -TRAC0170
C     CHANGE WHEN DATE INTERVAL OR AREA CHANGES                        TRAC0180

      READ 5,L,K1,(((TABLE(I,J,K),K=1,48),J=1,3),I=1,3)                TRAC0190
    5 FORMAT(2I3/(16F4.2))                                             TRAC0200
      READ 6,YYLAT,XXLONG                                              TRAC0210
    6 FORMAT(6F5.2)                                                    TRAC0220
      READ 10,((XLONG(I,J),J=1,3),I=1,3)                               TRAC0230
   10 FORMAT(9F7.3)                                                    TRAC0240
```

```
      READ 11,((YLAT(I,J),J=1,3),I=1,3)                                  TRAC0250
   11 FORMAT(9F7.3)                                                      TRAC0260
      READ 12,((OMEGA(I,J),J=1,3),I=1,2)                                 TRAC0270
   12 FORMAT(6F7.0)                                                      TRAC0280

C     PROCESS RAW OMEGA DATA TO FIT FORMAT - NOTE SECOND VEHICLE DATA    TRAC0290
C     IMMEDIATELY AFTER FIRST VEHICLE                                    TRAC0300

   14 READ 15,(S1(I),T(I),S2(I),I=L,K1)                                  TRAC0310
   15 FORMAT(6F10.3)                                                     TRAC0320
      READ 18,L3,FIXLAT,FIXLONG                                          TRAC0330

C     FIXLONG = EXPECTED LONGITUDE, FIXLAT = EXPECTED LATITUDE           TRAC0340

   18 FORMAT(I5,2F10.5)                                                  TRAC0350

C     PICK X(1), X(501),Y(1),Y(501), AS POSITIONS IN MIDDLE OF AREA USEDTRAC0360
C     AS CORRECTION STARTING POINTS FOR BOTH VEHICLES                    TRAC0370

      X(1)= 117.5                                                        TRAC0380
      Y(1)=32.0                                                          TRAC0390
      X(501) = 117.5                                                     TRAC0400
      Y(501) = 32.0                                                      TRAC0410
      L=L+1                                                              TRAC0420
      DO 16 I=L,K1                                                       TRAC0430

C     CORRECTION CONVERSION ROUTINE                                      TRAC0440

      YDIFF = Y(I-1)-YYLAT(2)                                            TRAC0450
      IF(YDIFF)25,25,30                                                  TRAC0460
   25 N1=1                                                               TRAC0470
      GO TO 35                                                           TRAC0480
   30 N1=2                                                               TRAC0490
   35 XDIFF = X(I-1)-XXLONG(2)                                           TRAC0500
      IF(XDIFF)40,40,45                                                  TRAC0510
   40 N2=1                                                               TRAC0520
```

```
      GO TO 47                                                          TRAC0530
   45 N2=2                                                              TRAC0540
   47 N3=XINTF(T(I))                                                    TRAC0550
      IF(N3.EQ.0)50,55                                                  TRAC0560
   50 N3=24                                                             TRAC0570
   55 W3=FLOATF(N3)                                                     TRAC0580
      VALUE1=TABLE(N1,N2,N3)                                            TRAC0590
      N1=N1+1                                                           TRAC0600
C     INTERNATIONAL DATE LINE AND EQUATOR TRANSITIONS NOT CONSIDERED    TRAC0610
      VALUE2=TABLE(N1,N2,N3)                                            TRAC0620
      XINEAR1=VALUE2+((VALUE2-VALUE1)*YDIFF/1.4)                        TRAC0630
      N2=N2+1                                                           TRAC0640
      VALUE2=TABLE(N1,N2,N3)                                            TRAC0650
      N1=N1-1                                                           TRAC0660
      VALUE1=TABLE(N1,N2,N3)                                            TRAC0670
      XINEAR2=VALUE2+((VALUE2-VALUE1)*YDIFF/1.4)                        TRAC0680
      IF(N2.EQ.2)58,59                                                  TRAC0690
   58 XINEAR3=XINEAR2+((XINEAR2-XINEAR1)*XDIFF/1.9)                     TRAC0700
      GO TO 158                                                         TRAC0710
   59 XINEAR3=XINEAR1+((XINEAR2-XINEAR1)*XDIFF/1.9)                     TRAC0720
  158 N3=N3+1                                                           TRAC0730
      IF(N3.EQ.25)60,65                                                 TRAC0740
   60 N3=1                                                              TRAC0750
   65 VALUE3=TABLE(N1,N2,N3)                                            TRAC0760
      TDIFF=VALUE3-VALUE1                                               TRAC0770
      SUB=T(I)-W3                                                       TRAC0780
      XINEAR4=XINEAR3+(SUB/.6)*TDIFF                                    TRAC0790
      N2=N2-1                                                           TRAC0800
      IF(N3.EQ.1)1,2                                                    TRAC0810
    1 N3 = 48                                                           TRAC0820
      GO TO 3                                                           TRAC0830
    2 N3 = N3+23                                                        TRAC0840
    3 VALUE1=TABLE(N1,N2,N3)                                            TRAC0850
      N1=N1+1                                                           TRAC0860
```

```
      VALUE2=TABLE(N1,N2,N3)                                                    TRAC0870
      XINEAR1=VALUE2+((VALUE2-VALUE1)*YDIFF/1.4)                                TRAC0880
      N2=N2+1                                                                   TRAC0890
      VALUE2=TABLE(N1,N2,N3)                                                    TRAC0900
      N1=N1-1                                                                   TRAC0910
      VALUE1=TABLE(N1,N2,N3)                                                    TRAC0920
      XINEAR2=VALUE2+((VALUE2-VALUE1)*YDIFF/1.4)                                TRAC0930
      IF(N2.EQ.2)66,67                                                          TRAC0940
   66 XINEAR3=XINEAR2+((XINEAR2-XINEAR1)*XDIFF/4.0)                             TRAC0950
      GO TO 68                                                                  TRAC0960
   67 XINEAR3=XINEAR1+((XINEAR2-XINEAR1)*XDIFF/1.9)                             TRAC0970
   68 N3=N3+1                                                                   TRAC0980
      IF(N3.EQ.49)70,75                                                         TRAC0990
   70 N3=25                                                                     TRAC1000
   75 VALUE3=TABLE(N1,N2,N3)                                                    TRAC1010
      TDIFF=VALUE3-VALUE1                                                       TRAC1020
      XINEAR5=XINEAR3+(SUB/.6)*TDIFF                                            TRAC1030
      S1(I)=S1(I)-XINEAR4                                                       TRAC1040
      S2(I)=S2(I)-XINEAR5                                                       TRAC1050

C     OMEGA LATITUDE AND LONGTUDE CONVERSION                                    TRAC1060

      ALFA1=1.0+S1(I)-OMEGA(1,1)                                                TRAC1070
      N1=XINTF(ALFA1)                                                           TRAC1080
      L1=XINTF(ALFA1+.5)                                                        TRAC1090
      ALFA2=1.0+S2(I)-OMEGA(2,1)                                                TRAC1100
      N2=XINTF(ALFA2)                                                           TRAC1110
      L2=XINTF(ALFA2+.5)                                                        TRAC1120
      DELTA1=OMEGA(1,L1+1)-OMEGA(1,L1)                                          TRAC1130
      DELTA2=OMEGA(2,L2+1)-OMEGA(2,L2)                                          TRAC1140
      DELTA3=S1(I)-OMEGA(1,N1)                                                  TRAC1150
      DELTA4=S2(I)-OMEGA(2,N2)                                                  TRAC1160
        Y(I)=YLAT(N1,N2)+(YLAT(L1+1,L2)-YLAT(L1,L2))*DELTA3/DELTA1+(YLATTRAC1170
     1(L1,L2+1)-YLAT(L1,L2))*DELTA4/DELTA2                                      TRAC1180
        X(I)=XLONG(N1,N2)+(XLONG(L1+1,L2)-XLONG(L1,L2))*DELTA3/DELTA1+(XTRAC1190
     1LONG(L1,L2+1)-XLONG(L1,L2))*DELTA4/DELTA2                                 TRAC1200
```

```
   16 CONTINUE                                                                  TRAC1210

C     EXPECTED POSITION ROUTINE                                                 TRAC1220

      IF(L3.EQ.0)76,74                                                         TRAC1230
   74 XP= FIXLONG-X(L3)                                                        TRAC1240
      YP = FIXLAT -Y(L3)                                                       TRAC1250
      X(L) = X(L)+XP                                                           TRAC1260
      Y(L) = Y(L)+YP                                                           TRAC1270
      L1 = L+1                                                                 TRAC1280

C     EXPONENTIAL SMOOTHING ROUTINE                                             TRAC1290

      DO 100 I = L1,K1                                                         TRAC1300
       X(I) = .4*X(I)+.6*X(I-1)                                                TRAC1310
       Y(I) = .4*Y(I)+.6*Y(I-1)                                                TRAC1320
  100 CONTINUE                                                                 TRAC1330
C     READ IN SECOND VEHICLE DATA                                              TRAC1340
    76 IF(L.EQ.2)77,79                                                         TRAC1350
    77 L = 501                                                                 TRAC1360
      K1= K1+500                                                               TRAC1370
      GO TO 14                                                                 TRAC1380
    79 L = 1                                                                   TRAC1390
      K1 = K1-500                                                              TRAC1400
      DO 120 I=1,K1                                                            TRAC1410
      DIST(I)=SQRTF((X(I)-X(I+500))*(X(I)-X(I+500))+(Y(I)-Y(I+500))*(Y(        TRAC1420
     1I)-Y(I+500)))                                                            TRAC1430
  120 CONTINUE                                                                 TRAC1440
      PRINT 125                                                                TRAC1450
  125 FORMAT(1H135X19HVEHICLE OUTPUT DATA///)                                  TRAC1460
      PRINT 130                                                                TRAC1470
  130 FORMAT(5X11HVEHICLE ONE30X11HVEHICLE TWO//)                              TRAC1480
      PRINT 135                                                                TRAC1490
  135 FORMAT(4X1HX9X1HY9X1HT7X4HDIST8X1HX9X1HY//)                              TRAC1500
      PRINT 140,(X(I),Y(I),T(I),DIST(I),X(I+500),Y(I+500),I=1,K1)              TRAC1510
  140 FORMAT(6F10.4)                                                           TRAC1520
```

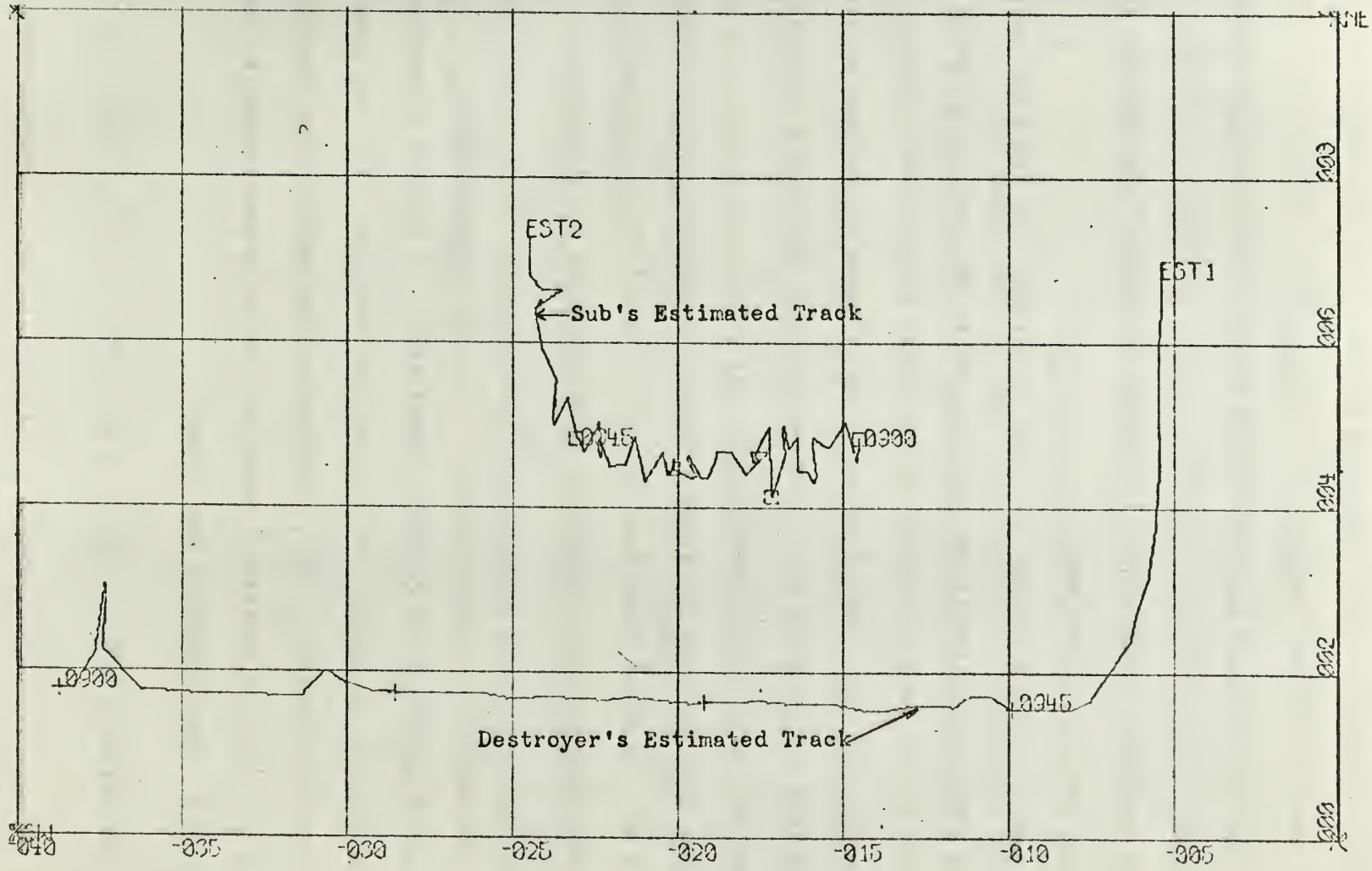
```
C     TRACK PLOTTING ROUTINE                                        TRAC1530

      DO 105 I=1,K1                                                 TRAC1540
      X(I) = -X(I)+117.6                                            TRAC1550
      Y(I) = Y(I)-32.47                                             TRAC1560
      Z(I) = -X(I+500)+117.6                                        TRAC1570
      W(I) = Y(I+500)-32.47                                         TRAC1580
  105 CONTINUE                                                      TRAC1590
      M2 = 4                                                        TRAC1600
      J = 1                                                         TRAC1610
      DO 210 I =1,M2                                                TRAC1620
      A(I) = X(J)                                                   TRAC1630
      B(I) = Y(J)                                                   TRAC1640
      C(I) = Z(J)                                                   TRAC1650
      D(I) = W(J)                                                   TRAC1660
      J = J + 15                                                    TRAC1670
  210 CONTINUE                                                      TRAC1680
      LAB7 = 8HNE  SW                                               TRAC1690
      LABEL1 = 4HEST1                                               TRAC1700
      LABEL2 = 4HEST2                                               TRAC1710
      LABEL3=8H09000945                                             TRAC1720
      LABEL4=8H09000945                                             TRAC1730
      IT(1)=8HAVTOMATI                                              TRAC1740
      IT(2)=8HC TRACK                                               TRAC1750
      IT(3)=8HRECONSTR                                              TRAC1760
      IT(4)=8HUCTION O                                              TRAC1770
      IT(5)=8HF TWO AS                                              TRAC1780
      IT(6)=8HW CRAFT                                               TRAC1790
      IT(7)=8HLT. R.A.                                              TRAC1800
      IT(8)=8HGARRETT                                               TRAC1810
      IT(9)=8H                                                      TRAC1820
      IT(10)=8H                                                     TRAC1830
      IT(11)=8H                                                     TRAC1840
      IT(12)=8H                                                     TRAC1850
      MM = 4                                                        TRAC1860
```

```
DX(1) = -0.0                                                                    TRAC1870
DX(2) = -0.4                                                                    TRAC1880
DX(3) = -0.0                                                                    TRAC1890
DX(4) = -0.4                                                                    TRAC1900
DY(1) = 0.1                                                                     TRAC1910
DY(2) = 0.1                                                                     TRAC1920
DY(3) = 0.0                                                                     TRAC1930
DY(4) = 0.0                                                                     TRAC1940
CALL DRAW(MM,DX,DY,1,1,LAB7,IT,0,0,0,8,0,2,8,8,1,LAST)                          TRAC1950
CALL DRAW(K1,X,Y,2,0,LABEL1,IT,0,0,0,0,0,0,8,8,0,LAST)                          TRAC1960
CALL DRAW(K1,Z,W,2,0,LABEL2,IT,0,0,0,0,0,0,8,8,0,LAST)                          TRAC1970
CALL DRAW(M2,A,B,2,2,LABEL3,IT,0,0,0,0,0,0,8,8,0,LAST)                          TRAC1980
CALL DRAW(M2,C,D,3,3,LABEL4,IT,0,0,0,0,0,0,8,8,0,LAST)                          TRAC1990
END                                                                             TRAC2000
```

VEHICLE OUTPUT DATA

VEHICLE ONE				VEHICLE TWO	
X	Y	T	DIST	X	Y
117.9874	32.4879	17.0000	.2441	117.7451	32.5186
117.9823	32.4879	17.0100	.2378	117.7461	32.5157
117.9758	32.4921	17.0200	.2277	117.7498	32.5205
117.9727	32.5005	17.0300	.2186	117.7548	32.5175
117.9741	32.4930	17.0400	.2163	117.7594	32.5188
117.9617	32.4878	17.0500	.2057	117.7578	32.5146
117.9544	32.4875	17.0600	.1971	117.7590	32.5131
117.9471	32.4872	17.0700	.1880	117.7610	32.5145
117.9384	32.4872	17.0800	.1798	117.7606	32.5145
117.9303	32.4872	17.0900	.1711	117.7614	32.5145
117.9236	32.4872	17.1000	.1622	117.7637	32.5145
117.9128	32.4874	17.1100	.1519	117.7642	32.5187
117.9056	32.4902	17.1200	.1414	117.7667	32.5172
117.9001	32.4887	17.1300	.1353	117.7685	32.5200
117.8926	32.4876	17.1400	.1290	117.7671	32.5173
117.8853	32.4876	17.1500	.1162	117.7715	32.5115
117.8786	32.4875	17.1600	.1109	117.7725	32.5200
117.8728	32.4875	17.1700	.1007	117.7765	32.5170
117.8668	32.4875	17.1800	.0961	117.7749	32.5157
117.8599	32.4874	17.1900	.0875	117.7770	32.5156
117.8518	32.4868	17.2000	.0795	117.7782	32.5170
117.8430	32.4872	17.2100	.0764	117.7728	32.5172
117.8388	32.4871	17.2200	.0649	117.7798	32.5141
117.8338	32.4870	17.2300	.0577	117.7844	32.5169
117.8282	32.4869	17.2400	.0499	117.7882	32.5167
117.8240	32.4868	17.2500	.0426	117.7910	32.5138
117.8163	32.4870	17.2600	.0352	117.7933	32.5137
117.8115	32.4870	17.2700	.0328	117.7972	32.5165
117.8024	32.4864	17.2800	.0287	117.7939	32.5138
117.7967	32.4864	17.2900	.0274	117.7952	32.5137
117.7920	32.4866	17.3000	.0299	117.8013	32.5150
117.7852	32.4865	17.3100	.0335	117.8009	32.5161
117.7785	32.4868	17.3200	.0364	117.8026	32.5141
117.7730	32.4865	17.3300	.0418	117.8039	32.5146
117.7673	32.4864	17.3400	.0485	117.8049	32.5169
117.7606	32.4863	17.3500	.0564	117.8101	32.5134
117.7538	32.4863	17.3600	.0676	117.8132	32.5187
117.7482	32.4859	17.3700	.0740	117.8161	32.5152
117.7435	32.4856	17.3800	.0808	117.8188	32.5152
117.7380	32.4855	17.3900	.0880	117.8209	32.5151
117.7308	32.4860	17.4000	.0988	117.8242	32.5184
117.7226	32.4861	17.4100	.1046	117.8228	32.5161
117.7169	32.4860	17.4200	.1108	117.8231	32.5176
117.7111	32.4874	17.4300	.1178	117.8242	32.5204
117.7050	32.4873	17.4400	.1274	117.8290	32.5169
117.6986	32.4858	17.4500	.1362	117.8308	32.5184
117.6932	32.4857	17.4600	.1457	117.8339	32.5236
117.6880	32.4856	17.4700	.1535	117.8376	32.5200
117.6804	32.4859	17.4800	.1610	117.8369	32.5235
117.6749	32.4869	17.4900	.1661	117.8371	32.5222
117.6676	32.4909	17.5000	.1720	117.8363	32.5251
117.6629	32.4939	17.5100	.1776	117.8375	32.5262
117.6609	32.4975	17.5200	.1832	117.8414	32.5293
117.6571	32.5014	17.5300	.1888	117.8431	32.5335
117.6552	32.5074	17.5400	.1875	117.8406	32.5353
117.6545	32.5133	17.5500	.1898	117.8431	32.5342
117.6546	32.5188	17.5600	.1811	117.8348	32.5365
117.6548	32.5248	17.5700	.1865	117.8409	32.5367
117.6547	32.5282	17.5800	.1868	117.8413	32.5362
117.6539	32.5332	17.5900	.1907	117.8446	32.5382
117.6539	32.5381	18.0000	.1915	117.8453	32.5430



X-SCALE = 5.00E-02 UNITS/INCH=6000 yards
Y-SCALE = 2.00E-02 UNITS/INCH=2400 yards

AUTOMATIC TRACK RECONSTRUCTION OF TWO ASW CRAFT

APPENDIX C-1

Exponential Smoothing

Exponential Smoothing is a special kind of moving average that does not require keeping a long record of previous positions. Like other moving averages, it has a stable response to changes, but the rate of response can be adjusted readily.

Suppose we adopted some such rule as follows: To get a new estimate of the average position of any vehicle, add to the previous estimate a fraction of the amount by which new positions exceeds that estimate. Note that under this rule, positions below the estimate is the same as saying it exceeded the estimate by a negative quantity, and adding a fraction of a negative quantity would decrease the estimate.

The fraction used is called a "smoothing constant" and is represented by α. We could abbreviate the rule in the form of an equation:

New estimate = old estimate + α(new position - old estimate)

or

New estimate = α(new position) + (1 - α) (old estimate).

This above process could continue indefinitely. A simpler representation may be achieved if we call the new position Position$_o$ (P_o), the next previous position Position$_1$ (P_1), the position two sequences ago Position$_2$, and so on, with the position k sequences ago being represented by Position$_k$ (P_k). Our expression now becomes

$$\text{New estimate} = \alpha P_o + \alpha(1-\alpha)P_1 + \alpha(1-\alpha)^2 P_2 + \alpha(1-\alpha)^3 P_3 + \ldots + \alpha(1-\alpha)^k P_k + (1-\alpha)^k \text{ (estimate made k sequences ago).}$$

The new estimate is then a sum of positions in past sequences, each multiplied by a definite weight. If the sum of these weights is equal to one, then the estimate can be called an average.

Therefore the basic rule of exponential smoothing is

New average = α(new position) + (1 - α) (old average).

How to Select α

The value chosen for the smoothing constant α determines how much of the past positions has any significant effect on the estimate of the average.

If a small value, say α = 0.01, is chosen for the smoothing constant, the response will be slow and gradual, since it is based on the average of very many past positions. A high value, say α = 0.5, will cause the estimates to respond quickly, not only to real changes, but also to the random fluctuations.

To evaluate alternative choices of a value for the smoothing constant, the accuracy of the positions must be considered along with the effects due to Auto-correlation. [4]

```
C     LTSQ SMOOTHING ROUTINE-REPLACEMENT FOR EXPONENTIAL ROUTINE [5]     00000005

      CALL LSQFT(K1,Y,YY)                                                00000 10
      CALL LSQFT(K1,X,XX)                                                00000 15
      DO 78 I=1,K1                                                       00000 20
      Z(I) = X(I+200)                                                    0000  25
      W(I) = Y(I+200)                                                    0000  30
   78 CONTINUE                                                           0000  35
      CALL LSQFT(K1,Z,ZZ)                                                00000 40
      CALL LSQFT(K1,W,WW)                                                00000 45
      SUBROUTINE LSQFT(M,F,COMP)                                         00000050
      DIMENSION F(250),ALPHA(33),BETA(33),SIGMA(33),S(33),P(33),X(250),C00000055
     1OMP(250),RERR(250)                                                 00000 60
      K=10                                                               0     65
      X(1)=1.                                                            000   70
      DO 43  I=2,M                                                       00000 75
   43 X(I)= X(I-1)+.01                                                   00000 80
   13 PRINT 16                                                           0000  85
   16 FORMAT (1H1)                                                       00000100
      CALL LSFIT (F,X(1),X(M),M,K,ALPHA,BETA,SIGMA,S,P,K1,SUP,K)         00000500
      PRINT 56                                                           00000510
   56 FORMAT(5X,75H ORIG ABSCISSA       ORIG ORDINATE       NEW ORDINATE00000520
     1        RELATIVE ERROR ///)                                       00000530
      DO 40 I=1,M                                                        00000540
      COMP(I)=VALUE(P,X(I),K1)                                           00000550
   40 RERR(I)= (F(I)-COMP(I))/COMP(I)                                    00000560
      PRINT 21,(X(I),F(I),COMP(I),RERR(I),I=1,M)                         00000570
   21 FORMAT  (4 E20.10)                                                 00000580
      END                                                                000* 590
      SUBROUTINE LSFIT(F,X1,XM,M,K,ALPHA,BETA,SIGMA,S,P,K1,SUP,L)        00000770
      DIMENSION  F(400) ,ALPHA(33),BETA(33),SIGMA(33),S(33),P(33),       00000780
     1CLASTP(34),PLAST(400),THISP(400),CTHISP(33),CPOLY(34),T(33)        00000790
      MU=0                                                               000   800
    1 FM=M                                                               000   810
      SWX1=0.                                                            0000  820
      SWX=1.                                                             0000  830
```

```
      BETA(1)=0.                                                        00000840
      CLASTP(1)=0.                                                      00000850
      CLASTP(2)=0.                                                      00000860
      DELSQ=0.                                                          00000870
      OMEGA=0.                                                          00000880
      CTHISP(2)=1.                                                      00000890
      THISW=FM                                                          00000900
      KK=K+1                                                            00000910
      DO 2 I=1,KK                                                       00000920
    2 T(I)=0.                                                           00000930
      DO 10 I=1,M                                                       00000940
      DELSQ =DELSQ + F(I)**2                                            00000950
      THISP(I)= 1.                                                      00000960
      PLAST(I)=0.                                                       00000970
   10 OMEGA = OMEGA + F(I)                                              00000980
      CPOLY(2)=OMEGA/THISW                                              00000990
      S(1)=CPOLY(2)                                                     00001000
      DELSQ =DELSQ - S(1)*OMEGA                                         00001010
      SIGMA(1) = DELSQ/(FM-1.)                                          00001020
      DELTAX = 4./(FM-1.)                                               00001030
      XONE = -2.                                                        00001040
      A= DELTAX * (FM-1.)/(XM-X1)                                       00001050
      B= XONE - A* X1                                                   00001060
      DO 9 I=1,K                                                        00001070
      SUP=0.                                                            00001080
      II=I+1                                                            00001090
      III=II+1                                                          00001100
      DUMMY = 0.                                                        00001110
      X= XONE                                                           00001120
      DO 14 J=1, M                                                      00001130
      DUMMY = DUMMY + X * THISP(J)**2                                   00001140
   14 X= X+ DELTAX                                                      00001150
      ALPHA(I+1)= DUMMY /THISW                                          00001160
      WLAST=THISW                                                       00001170
      OMEGA = 0.                                                        00001180
      THISW = 0.                                                        00001190
```

```
      X= XONE                                                                  00001200
      DO 15 J=1,M                                                              00001210
      DUMMY =BETA(I)*PLAST(J)                                                  00001220
      PLAST(J)=THISP(J)                                                        00001230
      THISP(J)=(X-ALPHA(I+1)) * THISP(J) - DUMMY                               00001240
      THISW = THISW +THISP(J)**2                                               00001250
      OMEGA = OMEGA +F(J)* THISP(J)                                            00001260
   15 X = X+DELTAX                                                             00001270
      BETA(I+1)=THISW/WLAST                                                    00001280
      S(I+1) = OMEGA/ THISW                                                    00001290
      DELSQ = DELSQ - S(I+1)* OMEGA                                            00001300
      SIGMA(I+1)=DELSQ/FLOATF(M-I)                                             00001310
      IF (SIGMA(I+1)) 1005,1001,1001                                           00001320
 1005 PRINT 1006,I                                                             00001330
 1006 FORMAT(//44H SIGMA SQUARE HAS NEGATIVE VALUE AT DEGREE  I5///)           00001340
      SUP=0.                                                                   00001350
      K=L                                                                      00001360
      RETURN                                                                   00001370
 1001 IF (SWX-1.) 25,6,25                                                      00001380
    6 IF (I-MU) 7,7,1000                                                      00001390
 1000 IF(SIGMA(I+1)-SIGMA(I)) 7,8,8                                           00001400
    8 IF (I-K) 40,7,40                                                        00001410
   40 SWX=0.                                                                  00001420
      MU=I                                                                    00001430
      TEST =.6*SIGMA(I)                                                       00001440
      SWX1=1.                                                                 00001450
      GO TO 7                                                                 00001460
   25 IF (I-K) 1002,7,1002                                                    00001470
 1002 IF (SIGMA(I+1)-TEST) 22,7,7                                            00001480
   22 GO TO 1                                                                 00001490
C     RECURSION FOR POLYNOMIAL COEFFICIENTS                                   00001500
    7 DO 16 J=2,II                                                            00001510
      DUMMY = CLASTP(J)* BETA(I)                                              00001520
      CLASTP(J)= CTHISP(J)                                                    00001530
      CTHISP(J)=CLASTP(J-1)-ALPHA(I+1)*CTHISP(J)-DUMMY                        00001540
   16 CPOLY(J) =CPOLY(J)+S(I+1)*CTHISP(J)                                     00001550
```

```
      CPOLY(I+2)=S(I+1)                                                 00001560
      CTHISP(I+2)=1.                                                    00001570
      IF (SWX1) 2001,2000,2001                                          00001580
 2001 DO 27 J=1,II                                                      00001590
   27 T(J)=CPOLY(J+1)                                                   00001600
      SUP=1.                                                            00001610
      SWX1=0 .                                                          00001620
 2000 CTHISP(I+2)=1.                                                    00001630
    9 CLASTP(I+2)=0.                                                    00001640
      IF (SWX) 31,30,31                                                 00001650
   31 DO 32 I=1,KK                                                      00001660
   32 T(I)=CPOLY(I+1)                                                   00001670
      SUP=1.                                                            00001680
      K1=K                                                              00001690
      GO TO 1003                                                        00001700
   30 K1=MU                                                             00001710
 1003 CALL POLYX(A,B,T,P,K1)                                            00001720
      END                                                               00001730
      SUBROUTINE POLYX (A,B,C,D,N)                                      00001740
      DIMENSION  C(33),D(33), Z(33), W(33)                              00001750
      W(1)=1.                                                           00001760
      Z(1)=1.                                                           00001770
      D(1)=C(1)                                                         00001780
      N1 = N+1                                                          00001790
      DO 10 I=2,N1                                                      00001800
      W(I)=1.                                                           00001810
      Z(I)= B* Z(I-1)                                                   00001820
   10 D(1)= D(1) +C(I)*Z(I)                                             00001830
      DO 12  J=2,N1                                                     00001840
      W(1)= W(1)*A                                                      00001850
      D(J)= C(J)*W(1)                                                   00001860
      K = 2                                                             00001870
      J1=J+1                                                            00001880
      DO 12  I=J1,N1                                                    00001890
      W(K)= A*W(K) + W(K -1)                                            00001900
      D(J)= D(J)+C(I)* W(K)* Z(K)                                       00001910
```

```
12 K = K + 1                                                    00001920
   END                                                          00001930
   FUNCTION VALUE(P,ARG,K)                                      00001940
   DIMENSION P(33),Q(33)                                        00001950
   KK=K+1                                                       00001960
   JK=K                                                         00001970
   DO 10 I=1,KK                                                 00001980
10 Q(I)=P(I)                                                    00001990
   DO 5 I=1,K                                                   00002000
   Q(KK)=Q(KK)*ARG+Q(JK)                                        00002010
 5 JK=JK-1                                                      00002020
   VALUE =Q(KK)                                                 00002030
   END                                                          00002040
```

APPENDIX C-III

METHODOLOGY TO BE USED FOR COORDINATE CONVERSION [6]

The procedure to be used for conversions of raw Omega data to absolute Latitude/Longitude (or the inverse) will be based on linear interpolation between a set of appropriately selected and stored points. The accuracy of the procedure will be insured by the methodology used to select the points to be stored.

The basis for the conversion in either direction will be three matrices of stored data. The first two define the crossing points in latitude/longitude of integral (but not necessarily consecutive) lanes of Omega phase differences. These points can be defined as:

L_{ij} = longitude of intersection of Omega lane i with Omega lane j

ℓ_{ij} = latitude of intersection of Omega lane i with Omega lane j

where the first index "i" refers to the lane number associated with phase difference between one set of two Omega signals and the second index "j" to another.

In addition to the position in latitude/longitude, it is necessary to store the actual Omega lane numbers of these crossing points.

Ω_{kr} = lane number associated with the "r"th stored crossing point for the "k"th station pair. There will normally be only two station pairs being considered at one time and it will be assumed that $\Omega_{kr} > \Omega_{k,r-1}$ to make searching more convenient. Note that for k=1, r = i and for k=2, r=j.

1. Omega to Latitude/Longitude

Reference to figure 1 indicates that one problem to be solved is to determine the Latitude/Longitude (L^*/ℓ^*) of the Omega fix (Ω_1^*, Ω_2^*) where the subscripts 1 and 2 define the station pair as the "k" index does in the $\Omega_{k,r}$ matrix.

By some search procedure it can be determined that Ω_1^* lies between $\Omega_{1,m}$ and $\Omega_{1,m+1}$, and similarly, $\Omega_{2,n} < \Omega_2^* < \Omega_{2,n+1}$. In addition Ω_1^* is closest to $\Omega_{1,\hat{m}}$ and Ω_2^* is closest to $\Omega_{2,\hat{n}}$. The equations defining L^* and ℓ^* then become:

$$L^* = L_{\hat{m},\hat{n}} + \frac{(L_{m+1,n} - L_{m,n})}{\Delta\Omega_1} \Delta\Omega_1^* + \frac{(L_{m,n+1} - L_{m,n})}{\Delta\Omega_2} \Delta\Omega_2^* \qquad (1)$$

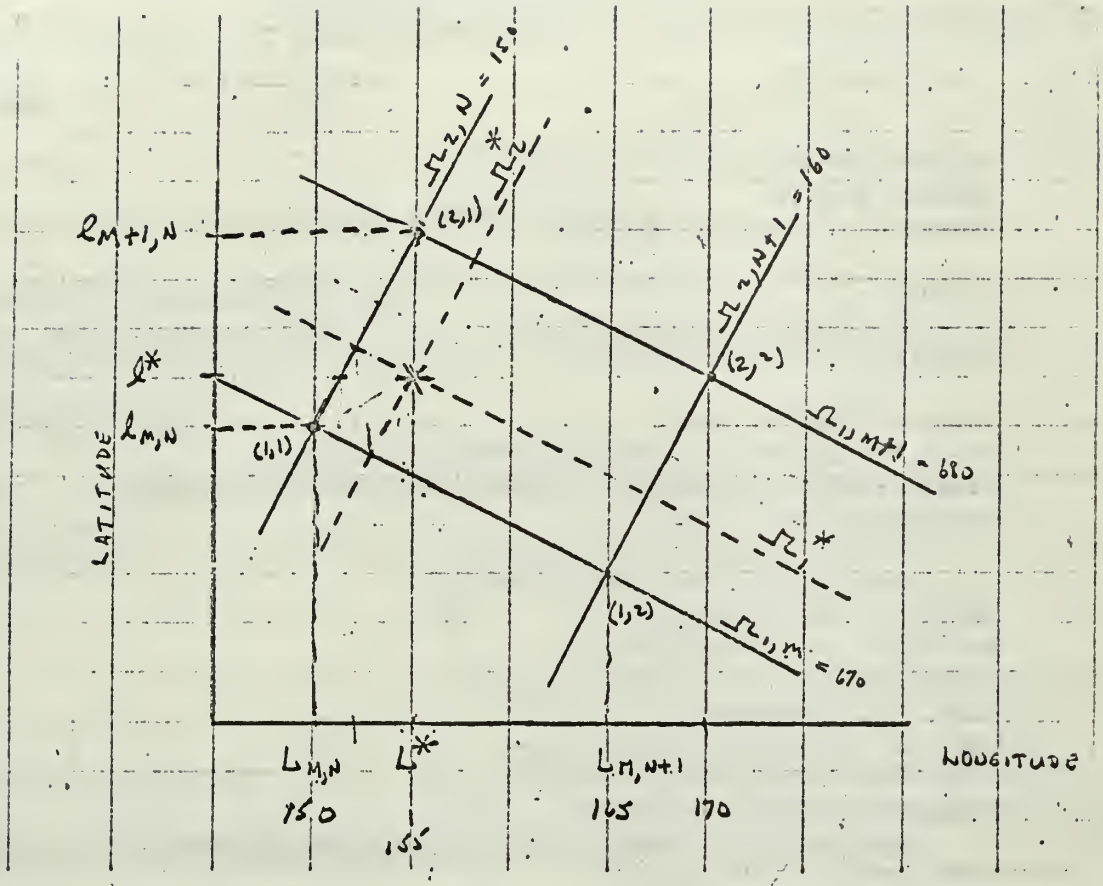


FIGURE 1: Geometry of conversion problem

$$\ell^* = \ell_{\hat{m},\hat{n}} + \frac{(\ell_{m+1,n} - \ell_{m,n})}{\Delta\Omega_1}\Delta\Omega_1^* + \frac{(\ell_{m,n+1} - \ell_{m,n})}{\Delta\Omega_2}\Delta\Omega_2^* \qquad (2)$$

where $\Delta\Omega_1 = (\Omega_{1,m+1} - \Omega_{1,m})$

$\Delta\Omega_2 = (\Omega_{2,n+1} - \Omega_{2,n})$

$\Delta\Omega_1^* = (\Omega_1^* - \Omega_{1,\hat{m}})$

$\Delta\Omega_2^* = (\Omega_2^* - \Omega_{2,\hat{n}})$

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The relative distance between various Antisubmarine Warfare vehicles is an important parameter for the evaluation of sensor equipment. This thesis presents a computer model, utilizing a time dependent error navigation system, Omega, for the determination of this relative distance parameter. A methodology for predetermining a relative distance error distribution for a specific area by simulating various Antisubmarine Warfare vehicle tracks from known navigational errors has been established. Attempts to smooth estimated tracks of Antisubmarine Warfare vehicles which receive the same time dependent navigational information simultaneously was found not to be advisable as this disturbs the correlation of navigation error between the vehicles.

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	ROLE	WT	ROLE	WT	ROLE	WT
Omega ASW Track Reconstruction ASW Sensory Evaluation						

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